Learning to Practice Medicine: Developing Medical Students' Acute Patient Management Skills Using a Longitudinal Program of Mannequin-Based Simulation

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Submitted in partial fulfilment of the requirements of the degree of Doctor of Education (with coursework component)

June, 2019

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Abstract

This qualitative study examines the development of medical students' acute patient management skills during participation in a longitudinal patient management simulation program. Current research shows that junior doctors feel ill-equipped to manage clinical deterioration in the acute healthcare setting due to a lack of skill and experience. It is also evident that conventional simulation facilitation practices are not meeting the learning needs of novice medical students. The focus of this study was to analyse the impact that a specifically designed simulation program had on the development, retention, and transfer of acute patient management skills for three groups of medical students during their medical school training.

Educational design research was used to develop and introduce two curriculum interventions to support learning. The two interventions were based on issues relating to the *content* and the *delivery* of the simulation program. Intervention 1 was the introduction of a clinical deterioration component to every case-based core presentation simulation in an established program. Intervention 2 was the introduction of a newly developed role of in-game coach, which replaced the original role of simulation facilitator.

In order to assess learning, retention, and transfer of acute patient management skills, video-recorded simulations were generated and analysed for learning progression. The coaching that supported student learning was analysed in order to conceptualise the new role more definitively and to create guidelines for supporting student learning. Focus group interviews complemented the data set and provided insights into the students' experiences and reflections as a result of taking part in the simulations. Learning frameworks were developed to show typical learning progression and can be further applied to support student learning through the provision of feedback, as an assessment tool, and to provide support to coaches.

The study found that repeated practice using standardised approaches to acute patient management enabled rapid retrieval of knowledge from long-term memory into working memory after an extended retention interval. A learning progression model identified a shift from novice to either competent or proficient practice in acute patient management skills at the completion of the program. Common misconceptions and difficulties for students at various stages of the progression were identified so that coaching can be targeted more effectively to support students. Local instruction guidelines based on the interventions and the data analysis have been developed as an output of this research.

Declaration

This is to certify that

1. the thesis comprises only my original work towards the EdD
2. due acknowledgement has been made in the text to all of the other material used
3. the thesis is approximately 64,000 words as approved by the RHD committee
4. the thesis has been professionally copyedited and proofread as per the Australian Standards for Editing Practice by a member of the Institute of Professional Editors (IPEd), as approved by the Graduate Research Examinations Officer, Graduate Research.

Jennifer Keast

June 2019

Acknowledgements

My sincerest thanks go to my three supervisors, Professor David Clarke, Professor Geoff McColl, and Dr Natasha Ziebell, for their support, encouragement, wise advice, and stimulating discussion at important stages of this research. I benefited greatly from having supervisors with vast and varied research experience. In particular, I am especially grateful to Natasha for her timely and unfailing guidance that enabled me to complete this thesis.

I also acknowledge the medical students who participated so eagerly in both simulation in general and in this research and will be forever grateful for their willingness to contribute so enthusiastically to the overall process over an extended period of time.

My thanks also go to the generous support I received on many levels from Professor Peter Morley. Also, a big thank you to my other work colleagues for their continued interest and encouragement in this project. I am also most grateful to Associate Professor David Pierce for his timely reading of the thesis and his thoughtful feedback. Thank you also to Carmel Mesiti at the MGSE for her inspirational advice and support.

From the very first time I was exposed to simulation-based education I was excited by its potential to provide unique learning opportunities to anyone fortunate enough to experience it. I have enjoyed a fascinating journey over the years, both observing and participating in its evolution. It has been an absolute pleasure to undertake this research, which I hope contributes in some small way to the ongoing development of simulation practice in health care.

A team effort is definitely required in order to complete a project such as this. Special thanks go to my family and friends for their constant encouragement and understanding. Also, to my faithful study buddies – Chappy and Jimmy – thank you both for keeping me company through some very long days of data coding. Most importantly, very special thanks and much love to my husband, Peter, for his extraordinary patience, selfless support, and steadfast faith in my abilities during this process.

Abbreviations and acronyms

AMPLE	Allergies/medications/past history/last eaten or lifestyle/event
DRSABCDEFG	Danger/response/send for help/airway/breathing/circulation/disability/exposure/(don't ever) forget glucose
ECG	Electrocardiograph (heart trace monitor)
MDANZ	Medical Deans Australia and New Zealand
MET	Medical emergency team
MONA	Morphine/oxygen/nitrates/antiplatelets
MONASH	Morphine/oxygen/nitrates/antiplatelets/stent-streptokinase-surgery/heparin
NSQHS	National Safety and Quality Health Service Standards
RIME	Reporter–interpreter–manager–educator
RRAD	Recognising and responding to acute deterioration
RRT	Rapid response team
SOCRATES	Site/onset/character/radiation/associations/time course/exacerbating-relieving factors/severity
STEMI	ST elevation myocardial infarction (heart attack)

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Introduction

Picture a group of medical students, with each student in the group standing around a high-tech, computerised patient mannequin in a simulated, life-like clinical environment, deeply immersed in role-playing junior doctors. They are participating in a patient management simulation scenario. Their coach has introduced their ‘patient’ with a ‘stem’ that sets the context and has given them an objective: to stabilise, diagnose, and manage the patient who is short of breath. Their task is to achieve this through previously learnt structured approaches to both clinical deterioration and clinical reasoning. A cognitive aid poster displaying this sequenced approach hangs on a whiteboard next to the patient. A team leader has been designated and has allocated roles to her team, and each team member is undertaking the tasks associated with their role and reporting information back to her. Patient data and progress notes are periodically updated on the whiteboard as a reminder to the team. Questions are asked, decisions are made, and management progresses. The coach supports students’ learning in the moment by challenging their thinking, prompting to guide and support decision-making, and assisting them to successfully reach the desired outcome or conclusion.

Figure 1. Simulation room. This picture shows a group of medical students participating in a team-based simulation. A team leader stands at the foot of the bed while other students assess the patient-mannequin. One student attends to the whiteboard, which displays a cognitive aid poster, and makes a note of relevant patient data for future reference.

Gaba's (2004) oft-quoted seminal definition of simulation as 'a technique to replace or amplify real-patient experiences with guided experiences, artificially contrived, that evokes or replicates substantial aspects of the real world in a fully interactive manner' (p. i2) remains embedded in the literature. As an educational activity, simulation provides opportunities for learning that are situated, immersive, and authentic. Examples include simulated and standardised patients (actors), low- and high-tech mannequins, part-task trainers (such as plastic limbs), screen-based (computer) simulations, virtual trainers with haptic feedback, and hybrid models (a combination of an actor with a plastic limb attached; Alklind Taylor, 2014; Issenberg, 2006). Simulation is 'a powerful learning tool to help the modern healthcare professional achieve higher levels of competence and safer care'. (Aggarwal et al., 2010, p. i34).

Within health care, there are three main foci of simulation use. First, simulation techniques can be used for learning, practice, and assessment of technical procedures such as surgical techniques. This can take a variety of forms ranging from simple part-task models such as plastic limbs to sophisticated virtual reality machines. Second, simulated or standardised patients are used to teach clinical and non-technical skills and are also used for performance-based assessment. Third, simulation technologies have been used for practising the management of rare events, team training, and improving performance in stressful, dynamic, and complex situations (McDougal, 2015; Motola, Devine, Chung, Sullivan, & Issenberg, 2013; Weller, Nestel, Marshall, Brooks, & Conn, 2012).

During medical training, many students perceive a lack of emphasis on patient management as compared with making a diagnosis (Sefton, Gordon, & Field, 2008). The aforementioned group of students is participating in a team-based clinical simulation designed to provide opportunities to learn key skills required for patient management across two domains: clinical deterioration and clinical reasoning. However, the simulation design in this case has undergone radical pedagogical adaptations from conventional simulation design, based on the specific needs of medical students learning in simulation. First, the simulation curriculum has been enhanced and extended with the aim of equipping medical students with the skills they will require as junior doctors to manage acute patient deterioration. Second, based on theory that informs instructional design, improved conditions for learning within simulation have been developed and a new coaching role is described.

Educational design research methodology (McKenney & Reeves, 2012) has been utilised to introduce and evaluate both of these adaptations to the simulation program. Described as 'interventions', the changes have been designed to modify pedagogy from two perspectives: *content* (what is being taught) and *process* (how it is being taught). These interventions are the result of two issues that arose separately but at similar times. One was the matter of junior doctors being ill-equipped to deal with patients who were acutely clinically deteriorating, especially in light of the fact that they were often the first ones called to the bedside in that setting (Alsaba & Brazil, 2018; Callaghan, Kinsman, Cooper, & Radomski, 2018). The other was a desire to improve traditional simulation teaching methods that no longer appeared as valid as previously thought. Pertinent learning theories and concepts such as the 'zone of proximal development' (Vygotsky, 1978), 'cognitive load theory' (Clark, Nguyen, & Sweller, 2006), 'flow theory' (Csikszentmihalyi, 1975) and 'metacognition' needed to be acknowledged and incorporated in the redesign of the curriculum.

Research questions

The issues outlined in the previous section provided the impetus for pedagogical changes in simulation-based learning designed to identify and implement improved learning conditions for medical students in order to answer the following major research question:

> To what extent does a longitudinally embedded patient management simulation program develop medical students' ability to systematically approach patient management, and what evidence is there of retention and transfer of these skills?

Contributing questions:

- What taskwork skills are students required to develop in order to manage acute patient management?
- How does teamwork impact on the students' capacity to complete those skills?
- How might instructional design in simulation be developed to support the processes required to develop those skills?
- How can a new role of in-game coach enhance learning in simulation?

- How can optimal conditions for learning in simulation be operationalised?

This is a study of hospital-based medical students in Melbourne, Australia, that arose out of a desire to improve patient simulation instructional design features in order to better meet the specific learning needs of second-year medical students and prepare them for future practice as junior doctors.

Overview of the thesis

Chapter 1 is the literature review that considers the three main elements of the study: learning, training, and simulation. These are addressed from the perspectives of skill acquisition and the development of expertise. The chapter contextualises the application of clinical reasoning skills, clinical deterioration skills, and teamwork skills utilised by junior doctors in the workplace. The discussion reveals the need for further training for medical students, especially in the setting of clinical deterioration. Simulation is offered as a suitable approach to training, and the world of serious gaming is looked to for instructional design methods. Theories underpinning both learning and instructional design are discussed and applied to a new model of simulation facilitation.

Chapter 2 provides a detailed description of the methodology and a rationale for using a qualitative approach employing educational design research. Video-recorded simulations, field notes, and focus group interviews make up the data set. This chapter also explains the approach to the selection of participants for the study, the way the data were gathered and analysed in order to address the research questions, and issues around reflexivity, rigour, and triangulation.

Chapters 3 and **4** present the findings and analysis of the data. Chapter 3 deals with findings on the development, transfer, and retention of taskwork and teamwork skills necessary for effective patient management from two perspectives: clinical deterioration and clinical reasoning. Chapter 4 describes the coaching episodes and cognitive supports required to enhance learning and the students' perceptions on their learning and their performance over the duration of the program. Their reflective comments are mapped against a model of expertise.

Chapter 5 is a discussion of the findings and draws on the results to develop local instruction guidelines to best support learning. Additionally, learning frameworks designed to capture student actions during the study are expanded for other uses such as providing feedback to learners and aiding simulation design and instructional support for coaches. The chapter includes a conclusions section that summarises the key findings in relation to the research questions and provides directions for future research.

Chapter 1 An introduction to patient management, learning in medicine, simulation-based learning, and the literature

1.1 Introduction

This chapter sets the scene for the research and is based on two main themes underpinning the rationale for the study. First, from the perspective of simulation curriculum *content,* the clinical reasoning and clinical deterioration skills required by junior doctors when they enter clinical practice and how those skills are currently learnt and developed is introduced. Second, from a *process* perspective, this chapter examines how those skills are taught and learnt in simulation-based education. Finally, a simulation instructional design model that addresses both *content* and *process* challenges will be presented. For a summary of the literature search methodology, please see Appendix A.

1.2 Patient management: Clinical deterioration and clinical reasoning

1.2.1 Clinical deterioration

Physiological deterioration occurs commonly in acute healthcare settings. Ensuring that patients who are acutely deteriorating receive appropriate and timely care is a key safety and quality challenge (Australian Commission on Safety and Quality in Health Care, 2018). Mismanagement of the deteriorating patient leads to increased adverse events including death, secondary morbidity, and prolonged intensive care admissions (Bucknall et al., 2017). Failure to recognise and appropriately manage clinical deterioration is a contributing factor in many adverse events in hospitals and healthcare settings worldwide and has generated international concern over patient safety (Australian Commission on Safety and Quality in Health Care, 2018; Cooper et al., 2011; DeVita, et al., 2010), Jones and Subbe (2018) identified from the literature five important factors regarding in-hospital patient clinical deterioration:

- Serious adverse events occurred in approximately 10% of hospital actions

- Serious adverse events were commonly preceded by signs of clinical deterioration
- The response of ward clinicians was often not commensurate to the degree of clinical deterioration
- The assessment and treatment of clinical deterioration on the ward preceding serious events was often suboptimal
- Escalation to senior staff did not always occur.

Promisingly though, rapid identification and appropriate management of the deteriorating patient is associated with reduced mortality and morbidity rates (Calzavacca et al., 2010). Medical schools must address the challenge of preparing medical graduates with the skills and knowledge required in the early detection and management of clinical deterioration (Carling, 2010).

Junior doctors are often the first doctor to be called to assess an acutely deteriorating patient. Simultaneously stabilising a deteriorating patient while struggling to make a diagnosis is usually a junior doctor’s greatest fear, yet they feel like it is expected that they can handle such issues (Callaghan et al., 2018; Clinical Excellence Commission, 2012; Marker, Mohr, & Ostergaard, 2019). Learning medicine under supervision is vastly different from assuming responsibility for patient management, especially in the setting of an acutely unwell and deteriorating patient. The newly found sense of responsibility described by junior doctors often makes them anxious about their competence to deal with such situations (Callaghan et al., 2018; Illing et al., 2008). Eraut (1994, p. 17) describes this as the need to 'make wise judgement under conditions of considerable uncertainty'.

In the non-routine setting of clinical deterioration, a different set of problem-solving skills to the clinical reasoning skills doctors apply in routine settings is required in order to recognise clinical deterioration and stabilise the patient. Although considered a form of clinical reasoning, the application of these clinical deterioration skills takes priority over the more traditional process of clinical reasoning such as that experienced by physiologically stable patients. Skills required in the setting of clinical deterioration must be applied rapidly without the clinician necessarily knowing the cause of the deterioration. In contrast, during routine clinical reasoning, a diagnosis is made, and a management plan is subsequently decided upon. In the setting of clinical deterioration, the reverse applies. Therapy comes before the formation of a definitive diagnosis in that stabilisation through patient management processes must be attempted as a priority in the setting of a potentially unknown diagnosis. This is because most clinical deterioration presents in the same way, despite the cause. For example, severe infection such as sepsis commonly presents as a patient with low blood pressure, a fast heart rate, and low blood oxygen concentration. This patient presentation also commonly applies to a patient experiencing such conditions as dehydration or heart failure. Precious time can potentially be wasted by initially thinking about the cause instead of first treating the symptoms. This reversal of routine practice is in direct contrast to previous teaching and is therefore a foreign concept for medical students. This requires a change in mindset for medical students and the development of a new cognitive skill.

1.2.2 Clinical reasoning

In routine situations, clinical reasoning is the cognitive process of thinking critically to form an accurate diagnosis and subsequent patient management plan (Barrows & Tamblyn, 1980). It is an essential skill for all clinicians in the development of their professional expertise and for also minimising diagnostic error (Ajjawi & Higgs, 2006; Croskerry, 2009; Norman & Eva, 2010). Clinical reasoning can be further broken down into two steps – *diagnostic* reasoning and *therapeutic* reasoning (McColl, 2008, p. 10). Diagnostic reasoning is the iterative problem-solving process of formulating diagnostic hypotheses based on information gleaned from the patient, the physical examination, and investigations such as blood tests. Hypotheses generated at this stage are known as differential diagnoses. Eventually, as the picture unfolds, a most likely or 'working' diagnosis is made. Therapeutic reasoning is the subsequent management plan developed and implemented to treat the condition. Clinical reasoning is therefore a key component of the medical curriculum and features of it are incorporated into the clinical encounters that medical students experience. In contrast, the acquisition of clinical deterioration skills has less focus in the curriculum and is usually addressed as a standalone curriculum unit or module, usually towards the end of medical training (The University of Melbourne, 2018).

Further explanation of clinical reasoning and clinical deterioration skills acquisition and development is discussed in the next section.

1.3 How doctors think and learn

1.3.1 Clinical reasoning

Clinical reasoning is a form of problem-solving, and the components can be simply represented as:

- taking an appropriate history of symptoms from the patient and collecting relevant data
- performing a physical examination on the patient
- generating a provisional and differential diagnosis
- testing (ordering, reviewing, and acting on test results)
- reaching a final diagnosis
- developing a management plan
- reflecting on certainty of decisions (National Academies of Sciences, Engineering, and Medicine, 2015).

Several models of diagnostic reasoning have been advanced over the years, including hypothetico-deductive reasoning and causal reasoning, to describe the process of hypotheses generation (Schwartz & Elstein, 2008). In contrast, other theories have identified knowledge representations as sources of hypotheses such as instance-based models (memory-based), prototypes (criterion-based), illness scripts (instance-based and prototypes), and semantic networks (interconnecting knowledge nodes; Monteiro & Norman, 2013).

Currently, the dominant popular model of diagnostic reasoning is the dual process theory (Croskerry, 2009; Kahneman, 2011; Norman & Eva, 2010; Schneider & Shriffrin, 1977). Two distinct systems of judgement are posited (Schwartz & Elstein, 2008) and are represented in Figure 2. Within dual processing, System 1, or implicit reasoning processes, are considered *intuitive* (fast, reflexive, and requiring minimal cognitive resources). System 2 processes are considered *analytical* (slow, deliberate, and demanding more conscious effort; Schwartz & Kostopoulou, 2019). The two processes are at either end of a continuum, as not all clinical reasoning fits entirely into one or the other of the systems (Croskerry, 2009).

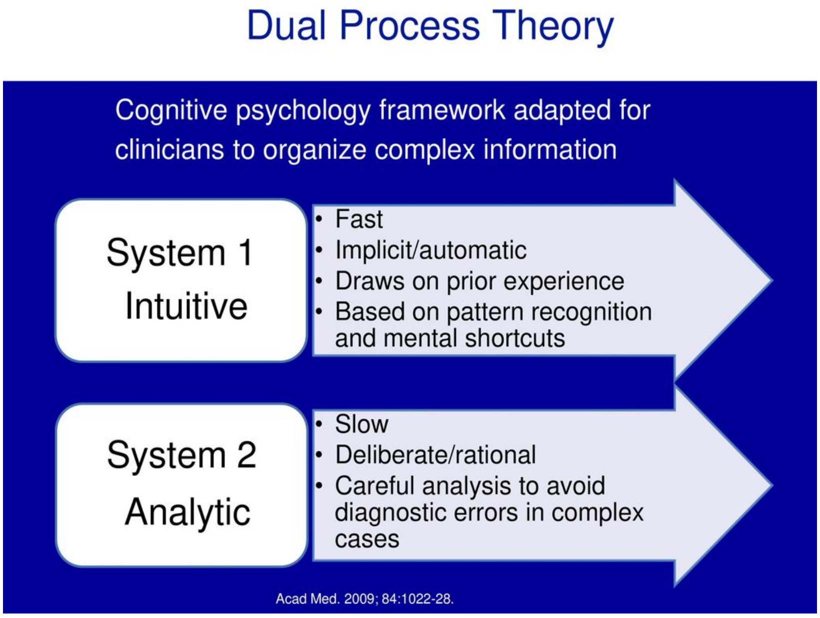

Figure 2. Dual process theory (Croskerry, 2009, p 1023).

At one end of the continuum, the intuitive approach 'relies heavily on the experience of the decision-maker and uses reasoning that depends on inductive logic' (Croskerry, 2009, p. 1022). In this system, experienced clinicians use pattern recognition techniques such as heuristics (mental shortcuts or 'rules of thumb') and 'thin-slicing' techniques (relying on instinctive first impressions; Croskerry, 2009, p. 1025). At the other end, the *analytical approach*, in contrast, involves critical thinking, and is logically sound based on hypotheses testing and deductive reasoning. This strategy involves first collecting all possible relevant data and then analysing the data for a diagnosis. It characterises the approach of novices, but experts may also employ it when diagnoses are rare or atypical (Croskerry, 2009).

From a practical perspective, if key features of the presentation are initially recognised, System 1 processes are activated instantly and automatically (Schwartz & Kostopoulou, 2019). Therefore, recognised visual presentations of a diagnosis or recognised combinations of salient symptoms or findings will activate pattern-recognition types of responses in System 1 (Croskerry, 2009). Pattern recognition is direct automatic retrieval of information from a well-structured knowledge base (Groen & Patel, 1985). Importantly, this process is automatic and intuitive – no deliberate thinking effort is involved (Croskerry, 2009; Kahneman, 2011). If the patient presentation is not recognised, or if it is 'atypical' or ambiguous or there is uncertainty, System 2 processes are activated instead. This system is an analytic one, examining the data, and attempting to make sense of the presentation by applying accepted rules of reasoning and logic (Croskerry, 2009).

There is much evidence to show that the best indicator for successful diagnostic reasoning is the quality of System 1 processing – chiefly the probability of the correct diagnosis being considered by the clinician (Tay, Ryan, & Ryan, 2016.). Research also suggests that the most common source of diagnostic error is the failure to switch to System 2 reasoning when System 1 is unsatisfactory (Graber, Franklin, & Gordon, 2005). Croskerry and Nimmo (2011) advise that the key to accurate decision-making is to be 'in the right mode at the right time' (p. 157). Croskerry, Singai & Mamede (2013) argue further that strong decision-making is a result of combining the two systems – switching between the two as the situation demands. They further posit that moving between the two systems requires awareness of which system you are using. Norman and Eva (2010), argue that strategies directed at encouraging both types of reasoning could lead to improved diagnostic accuracy.

According to van Merriënboer and Jeroen (2014), medical diagnosis can never be classified as System 1 or System 2 because they contain both consistent aspects (System 1) and variable aspects (System 2). They further argue that System 1 and System 2 processes occur and can be developed simultaneously. When used concurrently, they increase thinking efficiency, decision-making and action. (Quirk, 2006). Norman (2009) posits that both kinds of thinking are complementary and have a role in clinical reasoning.

A major focus of medical curricula is on the development of clinical reasoning skills. In particular, diagnostic reasoning comprises a large component of the examinable content of the curriculum. Rather than explicitly teaching clinical reasoning, medical schools teach medical knowledge and then provide opportunities for students to apply that knowledge in a variety of clinical settings (Connor, Dhaliwal, & Bowen, 2019). In their clinical years (the years after university that are spent in a hospital) students have clinical attachments in a variety of specialty areas in which their learning is focused on patients. The students perform medical interviews ('history taking'), physical examinations, and read associated patient history files that contain other information such as investigation results. At times, either formally as an assessment or informally as practice opportunities, the students present such a case to a clinician and receive feedback. Much of this patient-centred activity is self-directed and supported through didactic sessions such as tutorials and lectures. Some medical schools also use case-based simulation activities to complement learning in clinical reasoning.

The settings of the clinical encounter in which clinical reasoning by clinicians occurs range from general practice consultations to outpatient departments, and ward settings to emergency departments. Mostly, patients are physiologically stable (normal conscious state, blood pressure, heart rate, and blood oxygen percentage) and consultations can proceed in a structured manner. Therefore, speed of diagnosis is not critical in medicine except in certain circumstances, for example a rapidly deteriorating patient. However, physiological or clinical deterioration is relatively common in the acute hospital setting and, as discussed earlier, a different set of skills is required to manage this situation (Massey, Chaboyer, & Anderson, 2016). The Australian Commission on Safety and Quality in Health Care (2014) states the following:

> *One of the fundamental components of successful recognition and response systems is that all clinicians who provide acute patient care have the necessary skills and knowledge to keep patients who deteriorate safe from preventable harm. It is necessary to ensure that clinicians can accurately assess patients and interpret signs and symptoms of clinical deterioration; recognise the urgency of a situation; communicate to escalate care effectively; and provide immediate interventions while awaiting expert help. When clinicians lack the requisite skills to identify and interpret signs and symptoms of clinical deterioration and initiate early interventions, patients may not receive appropriate and timely treatment. (p. 4)*

1.3.2 Clinical deterioration

The Australian Commission on Safety and Quality in Health Care (2014) also outlines a number of key skills that all doctors and nurses should be able perform which include:

- *systematically assessing a patient*
- *understanding and interpreting abnormal physiological parameters and other abnormal observations*
- *initiating appropriate early interventions for patients who are deteriorating*
- *responding with life-sustaining measures in the event of severe or rapid deterioration, pending the arrival of emergency assistance. (p. 7)*

From a practical perspective, the skills required to manage clinical deterioration can be broken down into two interdependent components: taskwork and teamwork. Taskwork competencies are the knowledge, skills, attitudes, and other characteristics used to accomplish individual task performance (Salas, Rosen, Burke, & Goodwin, 2012).

Teamwork refers to 'the actual behaviour, cognition and attitudes that make interdependent performance possible' (Weaver, Feitosa, Salas, Seddon, & Vozenilek, 2013, p. 4). The essential link between the two elements of taskwork and teamwork is team cognition, which is the dynamic interaction (communication and coordination) that occurs among team members during work in a real-world context (Cooke, Gorman, Myers, & Duran, 2013).

1.3.2.1 Taskwork

The approach to the management of clinical deterioration is not all that complex, but it does require cyclical application of a series of steps that address threats to life in a systematic way. The situation is often dynamic, chaotic, and stressful. Non-routine situations such as this have high mental workloads due to stress (Waller, Gupta, & Giambatista, 2006). This is especially so when time for thinking is scarce. In addition to cognitive aspects of dealing with clinical deterioration on a knowledge-based level, the clinician must also manage their own stress (Kluge, 2014). Stress increases the risk of errors (Cannon-Bowers & Salas, 1998). This is especially relevant in the setting of a junior doctor who is often called to manage an unknown patient while working in an unfamiliar team – a common occurrence in large hospitals where the sheer number of staff mean that team members are often unknown to each other.

The reliance on a mnemonic such as 'DRSABCDEFG', which stands for danger, response, send for help, airway, breathing, circulation, disability, exposure and ('don't ever') forget glucose, aids in retrieval of information from long-term memory, especially in the setting of a stressful encounter. A mnemonic is a language aid used to support memory by chunking vast amounts of information into a manageable format for speedy retrieval (Loftus & Higgs, 2008). The evidence supporting the systematic DRSABCDEFG approach is expert consensus (Thim, Krarup, Grove, Rohde, & Lofgren, 2012). This approach is a widely accepted algorithm that aims to improve the speed and quality of treatment in the setting of clinical deterioration. Each letter of the DRSABCDEFG framework has corresponding steps, and within each step there are a number of components that need to be completed. Any physiological abnormality found is treated at the time, despite not necessarily knowing the cause of the deterioration. The steps are sequenced according to the threat to life and the initial assessment and treatment are performed simultaneously and continuously.

Each abnormality detected through application of the steps has a recommended management action and such action is potentially lifesaving. For example, if blood oxygen concentration is low, then oxygen is administered. The mnemonic is colloquially referred to as 'Doctors ABC', which makes it not only easy to remember but also, unlike other mnemonics, the order of each letter is important as it relates to the order in which the steps must be undertaken. For example, if the situation is dangerous (D), such as in the pre-hospital setting, then the rest of the steps are suspended until the danger is cleared. Another example is that breathing (B) is not assessed until the airway (A) is cleared or corrected. In other words, it is a sequential process, especially if the clinician utilising it is inexperienced.

As expertise increases and pattern recognition develops, the clinicians' application of the DRSABCDEFG structure can vary slightly depending on the patient presentation. Pattern recognition occurs when there are sufficient features of a patient's presentation to recognise a clinical pattern (Higgs & Jones, 2019). An example of this would be an immediate check of blood glucose levels in the setting of an alteration to conscious state levels to ensure that low glucose was not the cause. In that setting, checking the blood glucose levels would be a priority and would occur sooner in the process than the mnemonic states in order to correct it early. Using this structured approach is considered a hallmark of the initial care of clinical deterioration through optimal use of time and early recognition of physiological abnormalities. Other abnormalities include alteration to conscious state, breathing problems, low blood oxygen concentration, low blood pressure, and changes to heart rhythm.

The taskwork skills represented in Table 1 are considered generic to all patients requiring initial stabilisation prior to ongoing management despite the reason for the deterioration, whether it be a heart attack, stroke, trauma, or other causes. This is because the signs of clinical deterioration are similar despite the underlying cause and therefore it is not necessary to identify the underlying cause when undertaking initial assessment and stabilisation of a patient.

Table 1. Patient stabilisation taskwork skills

Step	Assessment	Action
D – Danger	Check for danger	Ensure safety
R – Response	Use AVPU to check patient response	Recovery position
S – Send for help	As required	
A – Airway	Airway noises	Suction Airway opening manoeuvres
B – Breathing	Chest rise and fall Symmetry Respiratory rate Auscultate Oxygen saturation	Oxygen Assist ventilation
C – Circulation	Heart rate Blood pressure Capillary refill Jugular Venous Pressure Mucous membranes Electrocardiogram	Elevate legs Intravenous fluids
D – Disability	Pupils Limbs	
E – Exposure	Expose	
(DE)FG – Don't ever forget glucose	Blood glucose	Administer glucose

Note: AVPU = Alert, voice, pain, unresponsive

Use of this structured approach aids in rapid and systematic patient assessment and stabilisation. A key feature of this approach is that despite the linear form the mnemonic takes within the table, the application is actually a cyclical one, as each time FG is reached, D for danger is rechecked, and the cycle recommences, as illustrated in Figure

3. This cycle continues until the patient has been adequately stabilised. This is an important point for anyone utilising the approach, in particular for a junior doctor who may not have the clinical reasoning skills required to ultimately diagnose the cause of deterioration. In this situation, a junior doctor is able to stabilise the patient to the best of their ability by continuing to recycle through the steps until more senior help arrives. Additionally, recycling through the steps not only ensures that the patient is being continually monitored, but also that the effect of implemented management actions is continually reassessed. For example, rechecking the blood pressure during a recycle informs ongoing decision-making about the intravenous fluids that were initiated to treat the blood pressure in the first place.

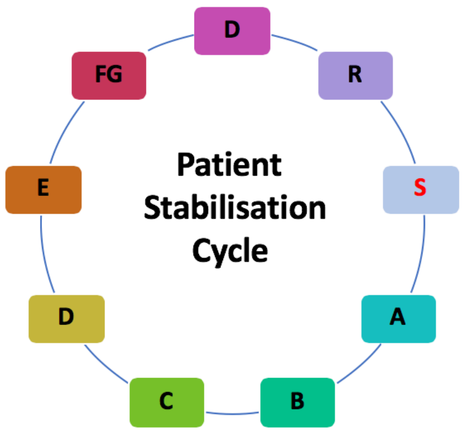

Figure 3. The patient stabilisation cycle.

Please note that S represents **send for help** and can be done at any time during the cycle as required.

1.3.2.2 Teamwork

Medicine is characterised by multiplex environments, partly due to the requirement that teams work together to solve complex problems in a time-critical manner with the major consequence of patient harm if they are unable to function effectively as a team (Salas et al., 2012). As previously stated, junior doctors are often the first doctor to be called to the bedside to review a patient whose clinical status has deteriorated. Depending on the patient's condition, either the doctor and nurse will continue to monitor and manage the patient, or more senior clinical assistance will be requested. Either way, an ad hoc team has formed to treat the patient. A team is defined as 'a set of two or more individuals that adaptively and dynamically interacts through specified roles as they work toward shared and valued goals' (Salas, Dickinson, Converse, & Tannenbaum, 1992, p. 4). More often than not in this setting, especially in large hospitals, the team members are not known to each other, which compounds an already challenging situation. Poor teamwork has been identified as a major contributor to poor patient outcomes and medical error (Chalwin & Gillon, 2018; Morey et al., 2002; Neily et al., 2010). One of the most common reasons for poor team formation and poor teamwork is a lack of shared understanding about the situation (St. Pierre, Hofinger, & Buerschaper, 2008) and a lack of leadership. Effective leadership behaviours can be a particular challenge in dynamic environments, as junior doctors do not feel they have the 'positional authority' to take a leadership role (O'Connor et al., 2016, p. 340). This in turn makes them reluctant to declare themselves the leader, which risks a leader not being appointed at all, especially if the junior doctor is also working with junior nurses who feel similarly anxious about that role (Massey et al., 2017). Teamwork skills are nationally recognised elements for training and competencies in the recognition and management of the deteriorating patient (Australian Commission on Safety and Quality in Health Care, 2014).

Teamwork skills comprise both a behavioural (teamwork tasks) and a cognitive (teamwork knowledge) component (Kluge, 2014). Wildman et al. (2012) describe team knowledge as:

- task-related knowledge (team mental models and task knowledge),
- team-related knowledge (the capabilities and characteristics of team members),
- process-related knowledge (team mental models of communication, leadership, and coordination), and
- goal-related team knowledge (team mental models of goals, objectives, and achievement). (p. 92)

Of particular importance in the setting of clinical deterioration is the coordination of actions to ensure all steps of the DRSABCDEFG cycle are completed in a timely manner, and crucial patient information is not overlooked or omitted. In order to achieve this, Salas et al. (2012) proposed a 'big five' of teamwork competencies:

- Team leadership – searching for and structuring information
- Adaptability – the team's ability to change performance processes in response to environmental cues
- Mutual performance monitoring – monitoring other team members' work
- Backup behaviour – providing resources to a team member
- Team orientation – a focus on teamwork over individual taskwork. (p. 42)

In addition to these competencies, three coordinating strategies were also developed by Salas et al. (2012) that facilitate the enactment of the five competencies:

- Shared mental models – organised knowledge structures that facilitate execution of interdependent team tasks
- Closed-loop communication – a communication pattern that enables effective teamwork
- Mutual trust – team members perform particular actions important to its members. (p. 45)

A combination of all of these cognitive teamwork processes contribute to enhanced team performance resulting in low-error, high-quality patient care (St. Pierre et al., 2008).

1.3.2.3 Team cognition

Common cognition among team members is associated with team effectiveness (Rentsch & Woehr, 2004). One definition of team cognition encompasses the organised structures that support team members' ability to acquire, distribute, store, and retrieve critical knowledge (Bell, Kozlowski, & Blawath, et al., 2012).

Two types of team cognition are described. First, *team member schema similarity* refers to the knowledge the team has about *teamwork* processes within the team (Rentsch & Woehr, 2009, p. 15). Schemas, or schemata, are abstract knowledge structures that organise vast amounts of information and the relationships among them (Gagne, Yekovich, & Yekovich, 1993). They are formed either through particular experiences or through interaction with others and may contribute to pragmatic reasoning (Chapparo & Ranka, 2019). Schemas are dynamic and adapted through similar new experiences, which either complement or elaborate existing schema. New experiences that are radically different may cause a 'cognitive restructuring' resulting in the formation of new schema (Rentsch & Davenport, 2006, p. 406).

Rentsch and Woehr (2009) refer to team member schema similarity as 'the degree to which team members have similar knowledge structures for organising and understanding *team* phenomena' (p. 15). In this definition it is assumed that cognition originates within each team member as a formal structure, or schema. Similar, but not identical, schemata are shared that are compatible with other team members' schema. In other words, team member schema similarity is the shared cognition between team members about task functioning (Rentsch & Davenport, 2006).

Second, *shared team mental models* refer to the knowledge shared by the team about the *taskwork* required to achieve the desired goal (Hinsz, 2009). Mental models are also knowledge representation models and include different types of knowledge such as declarative (knowledge of what), procedural (knowledge of how), and strategic (knowledge of context and application; Rouse, Cannon-Bowers, & Salas, 1992). Team mental models are team members' shared representation of knowledge relevant to key elements of the team's *task* environment (Rentsch & Woehr, 2009). That knowledge allows team members to similarly interpret information, share expectations concerning patient outcomes, and develop similar representations of the situation (Fernandez et al., 2017). Not surprisingly, team mental models are most critical during tasks requiring high levels of interaction and team member interdependence (Minionis, Zaccaro, & Perez, 1995). When decisions with potentially serious consequences must be made such as during clinical deterioration, 'the contribution of multiple team members will either result in superior decision making or result in safer performance' (Salas & Fiore, 2009, p. 3).

Ultimately, team mental models ensure that the entire team has a collective understanding of the current and future state of the situation and an understanding of how to achieve task goals. In association with team member schema similarity, it makes up the two dimensions of team cognition required for effective team performance.

1.4 The development of expertise

Theories of professional expertise development provide different perspectives that contextualise this domain. Eraut's (1994, p.100-122) perspective is that the development of expertise not only includes propositional knowledge (‘knowing that’), and process knowledge (‘knowing how’) but also that these are combined with personal experience. Klein and Militello (2004, pp. 335–342) have identified the following cognitive elements that distinguish experts from novices, which are shown in Table 2.

Table 2. Expert cognitive elements

Cognitive element	**Explanation**
Mental models	Experts have richer mental models and understand a wider range of causal connections that determine how things work. They can apply them flexibly as the situation changes.
Perceptual skills	Experts have developed perceptual skills that enable them to notice subtle cues and patterns and make fine discriminations that are not visible to novices.
Sense of typicality	Experts have accumulated patterns and experiences into prototypes, so they can judge when an event is typical or atypical.
Routines	Experts have developed a varied set of routines in order to address problems.
Declarative knowledge	Experts have a lot of factual information, rules, and procedures to draw on.

Experts draw on these elements more effectively than novices in order to make sense of the situation, to make dynamic decisions, and to plan and coordinate activities effectively and efficiently (Crandall, Klein, & Hoffman, 2006).

1.4.1 Expertise in clinical reasoning

In medicine, knowledge acquisition and clinical reasoning occur in tandem (Boshuizen & Schmidt, 1992). Development of clinical reasoning skills is due to structural changes in knowledge. Boshuizen and Schmidt (2019, pp. 57–76) describe three stages in the development of clinical reasoning:

1. The first stage consists of the acquisition of large amounts of bioscience knowledge. Concepts are linked together in a knowledge network. Over time, more concepts are added and refined and improved connections are made. The

reasoning process is characterised by lines of reasoning consisting of chains of small steps based on biomedical concepts. ‘Knowledge encapsulation’ describes the development of a direct line of reasoning between different concepts within networks. Repeated activation of these lines results in concepts clustering together in such a way that direct links are made between the first and last concept thus omitting the intermediate step.

2. In the next stage, encapsulation results in the integration of biomedical knowledge into clinical knowledge. The reasoning process no longer involves as many biomedical concepts, with direct links being made between patient findings and clinical concepts in the form of hypotheses or diagnoses. Biomedical knowledge is recalled if the problem is complicated.
3. Simultaneously, another type of structure – ‘illness scripts’ – is being developed. These comprise three components:
   (a) enabling conditions – conditions under which the disease occurs (e.g. medical, hereditary or environmental factors)
   (b) fault – the pathophysiology or cause of the disease
   (c) consequences of fault – signs and symptoms of the disease.

Once illness scripts have been activated there are no active small-step searches within that script as all elements of the script are activated automatically. Illness scripts also prompt expectations about other signs and symptoms the patient may have that can be investigated (Custers, 2015). Experts have vast numbers of well-developed illness scripts that are triggered as an automatic or unconscious process in which no active reasoning is required (Feltovich & Barrows, 1984). It is only in the case of a mismatch that active reasoning occurs. On the other hand, novices rely on less well-developed and less easily activated knowledge networks, which they have to actively search through to verify or falsify their hypotheses (Boshuizen & Schmidt, 2019).

Groen and Patel (1985) add a further developmental category, that of instance scripts, which represent the comparisons made between previous instances of the same illness that result in the emergence of pattern recognition. Pattern recognition is a type of short cut that represents a complex mental process involving recognising the salient cues of a presentation and the fast retrieval of an appropriate match from long-term memory (Coderre, Mandin, Harasym, & Fick, 2003). Most experienced clinicians diagnose through pattern recognition in that the words patients use to describe their symptoms trigger a particular prototype thought response developed through previous experience. It is only when the patient does not fit the typical prototype that experts return to the slower hypothesis-testing approach to approach a problem (Jones, Jensen, & Edwards, 2008).

According to Connor, Dhaliwal and Bowen (2019, pp. 17–51), at the foundational-year level of training, medical students should be able to

- recognise and summarise the key features of the patient's complaint
- identify relevant data relating to the complaint
- identify relevant contextual information pertaining to the complaint
- identify matches and mismatches between the patient's complaint and the typical features of illness scripts.

In their final year of training, medical students, according to Connor, Dhaliwal and Bowen (2018, pp 17-51), should be able to

- identify the most likely, less likely, and can't miss diagnoses
- defend the most likely diagnosis based on the data
- explain why other diagnoses are less likely
- describe how the likelihood of a diagnosis is affected by pre-test and post-test probability
- develop diagnostic approaches to commonly encountered clinical problems.

One practical way of conceptualising medical student progression in clinical reasoning is the application of Pangaro's (1999) reporter–interpreter–manager–educator (RIME) framework, which was later adapted to reflect skills rather than roles: reporting–interpretation–management–education (DeWitt, Carline, Paauw, & Pangaro, 2008). This framework maps the development of clinical reasoning skills through its application as a formative evaluation tool (see Table 3).

Table 3. An abridged version of the adapted RIME framework (DeWitt et al., 2008)

Reporting	Gathers pertinent data, reports in an organised fashion
Interpretation	Justifies and demonstrates clinical reasoning when prompted
Management	Almost always able to suggest appropriate tests or therapy
Education	Understands and applies evidence-based medicine concepts

Clinical reasoning is developed through experience and is often rapid, dynamic, complex, context-specific recognition (Ajjaw & Higgs, 2011; Delaney & Golding, 2014). Accordingly, healthcare curricula focus heavily on the acquisition of clinical reasoning skills which are key to optimising patient outcomes, yet students often complete their educational programs armed with theoretical knowledge but lack many of the skills vital for their work (Al-Elq, 2010). Clinical reasoning is learnt informally through experiential opportunities during the students' clinical years. However, in practice, clinical reasoning is undertaken by expert clinicians in a dynamic environment where factors relating to patient care take priority. Students observing such patient interactions cannot 'see' how the expert is thinking and are thus often left wondering how a particular decision was reached. Additionally, even if there were opportunities at the time for students to explore clinical thinking, experts are usually unable to describe their thinking or reasoning processes (Reilly, 2007). Meyer and Land (2010) highlighted that much of the knowledge held by professionals is tacit. That is, it is difficult for them to articulate their thought processes as it has become so inculcated that they use it without thought. Subsequently, students find it difficult to make sense of it when it is essentially invisible to them (McAllister & Rose, 2008). As a result, the challenge for educators is that clinical reasoning is an extremely difficult skill to teach students.

1.4.2 Expertise in clinical deterioration

Automation of the steps in the DRSABCDEFG approach ensures a systematic approach to patient management and prevents omission of vital information. The DRSABCDEFG framework previously illustrated differs slightly from other similar frameworks used in the setting of the deteriorating patient by more expert clinicians. In particular, when a rapid response team (RRT) or a medical emergency team (MET) is called to the bedside, the framework used by those teams is less detailed in some components and more detailed in others. Being experienced clinicians, RRT and MET team members have expertise that allows them to identify patient abnormalities more intuitively (i.e., without such thorough patient data collection) through strategies such as pattern recognition. Associations of signs and symptoms generate patterns that experts quickly recognise but which have little meaning for students (Sefton et al., 2008). Additionally, once they do prioritise abnormalities, experienced clinicians have a larger range of choices to address the problems than novice medical students. An example of this would be senior clinicians using intravenous drugs to treat low blood pressure rather than just the intravenous fluid administration available as an option to junior doctors. Ericsson (2006) describes this as 'expert performance counteracting automaticity through the development of increasingly differentiated mental models in order to control their performance' (p. 685).

Until such expertise develops, a more 'algorithmic' approach to clinical deterioration means that the basics are not overlooked by novices. Automaticity of both taskwork and teamwork skills is achieved through repeated exposure to situations where the skills are applied (Clark et al., 2006). This results in the formation of schemas that not only organise knowledge, as mentioned earlier in this chapter in section 1.3.2.3., but can reduce working memory load when a highly complex schema eventually becomes one unit in working memory (Clark et al., 2006). In the setting of clinical deterioration, working memory is then freed up to address diagnostic reasoning strategies to find the source of the deterioration.

1.4.3 Expertise in teamwork

The unique nature of ad hoc and temporary team formation in the setting of clinical deterioration can be likened to Hollenbeck, Beersma, and Schouten's (2012) 'decision-making teams' (p. 89), which form in the setting of non-routine events. The focus in this setting is often on understanding as a team, what is currently occurring, and why it has happened in order to make decisions. This is in sharp contrast to other healthcare teams (such as a rehabilitation team) who work together on a routine basis and share team familiarity.

As well as team behavioural skills, effective team performance necessitates team members possessing teamwork knowledge structures that are complex, dynamic, and coherent (Rentsch, Heffner & Duffy, 1994; Weaver et al., 2013). This knowledge is accumulated and stored as schema through the 'accumulation of instances of teamwork episodes' (Kluge, 2014, p. 135). In order to convert team knowledge into team behaviour, it is advised that training should be aimed at intact teams rather than at individuals (Mathieu, Maynard, Rapp, & Gilson, 2008; Swezey & Salas, 1992). In this way, team members can integrate and coordinate their teamwork skills into action together before applying them in other teams later (Mathieu et al., 2008; Reagans, Argote, & Brooks, 2005). Once an individual's schema has been developed to organise teamwork knowledge and they become increasingly more expert, they are more likely to transition smoothly in to other teams (Rentsch, Heffner, & Duffy, 1994). Knowledge retained and transferred to new environments provide the foundation for the next phase of teamwork expertise development (Kozlowski, 1998).

1.4.4 Triple-loop learning

One way to conceptualise the process of overall patient management in the setting of clinical deterioration is to apply triple-loop theory to the situation. Based on Argyris and Schön's (1978) double-loop learning framework, the extended triple-loop theory as an instructional guideline ensures all components of patient management are considered. According to Argyris (1999), single-loop learning occurs 'whenever an error is detected and corrected without questioning or altering the underlying values of the system', and double-loop learning occurs 'when mismatches are corrected by first examining and altering the governing variables and then the actions' (p. 68). A number of authors have described a further type of learning described as 'triple-loop' learning (Flood & Romm, 1996). This is often described as additional to double-loop learning and includes a reflective or metacognitive phase. Although traditionally used in the domains of organisation and business, application of this theory assists in identifying the necessary processes requiring application in acute patient management. The theory also assists in conceptualising the development of expertise over time.

Single-loop (Loop 1) learning is known as 'following the rules' (illustrated in Figure 4). In this loop, actions are based on fixing the current problem. In medicine, this loop represents an unexpected event, such as clinical deterioration, and the necessary steps required to fix the problem. A simplistic example of this would be an abnormal drop in a patient's blood pressure dealt with by administration of intravenous fluids (a standard approach) as represented in Figure 4. This is a procedural response to a situation in that the action of administering intravenous fluids is performed by a junior doctor in response to low blood pressure *despite* the cause (which may be unknown). The anticipated result would be that the blood pressure increases. At this stage, this action only removes the symptom (of low blood pressure) but the cause remains unsolved.

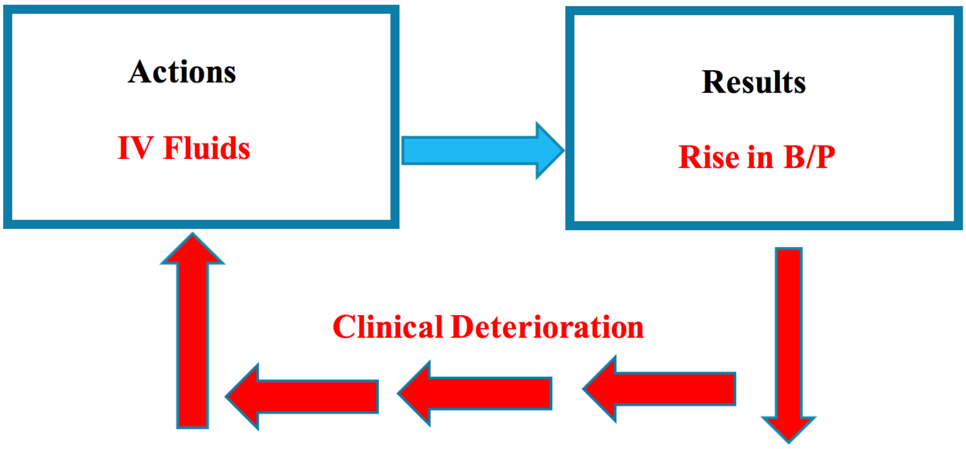

Figure 4. Loop 1. Adapted from Thorsten's Wiki as cited in Organisational Learning, 2014).

Note. IV = Intravenous B/P = Blood pressure

Double-loop (Loop 2) learning is known as 'changing the rules' (illustrated in Figure 5). In this loop the underlying cause needs to be corrected. This step requires clinical reasoning approaches to find the cause of the fall in blood pressure. In this example, one cause could be sepsis requiring antibiotics and possible ongoing intravenous fluids.

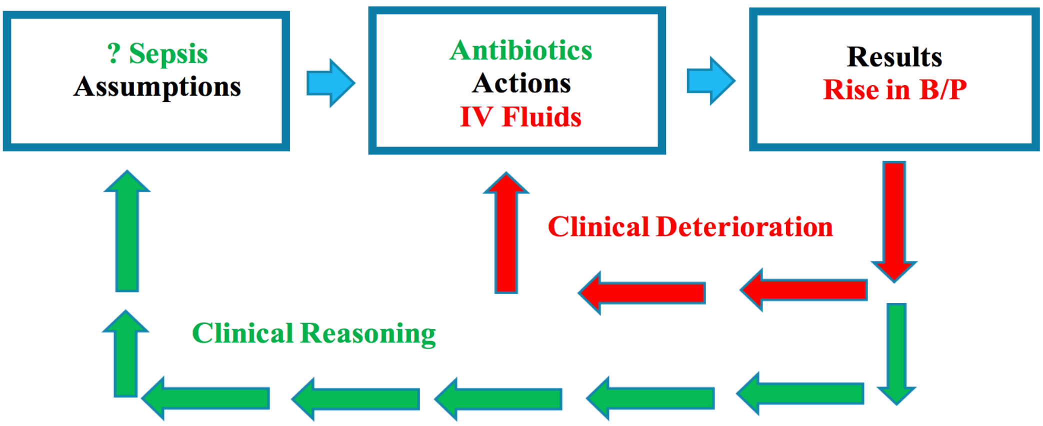

Figure 5. Loop 2. Adapted from Thorsten's Wiki as cited in Organisational Learning, 2014).

Note. IV = Intravenous B/P = Blood pressure

Triple-loop (Loop 3) learning is 'learning about learning' through reflection on action (illustrated in Figure 6). This should address the question of how to decide what is right. In this example, that would mean reflecting on other possible causes of low blood pressure. It may appear in System 1 thinking that sepsis is the most likely cause. However, it is important to prevent diagnostic bias by considering other causes that need to be addressed and eliminated.

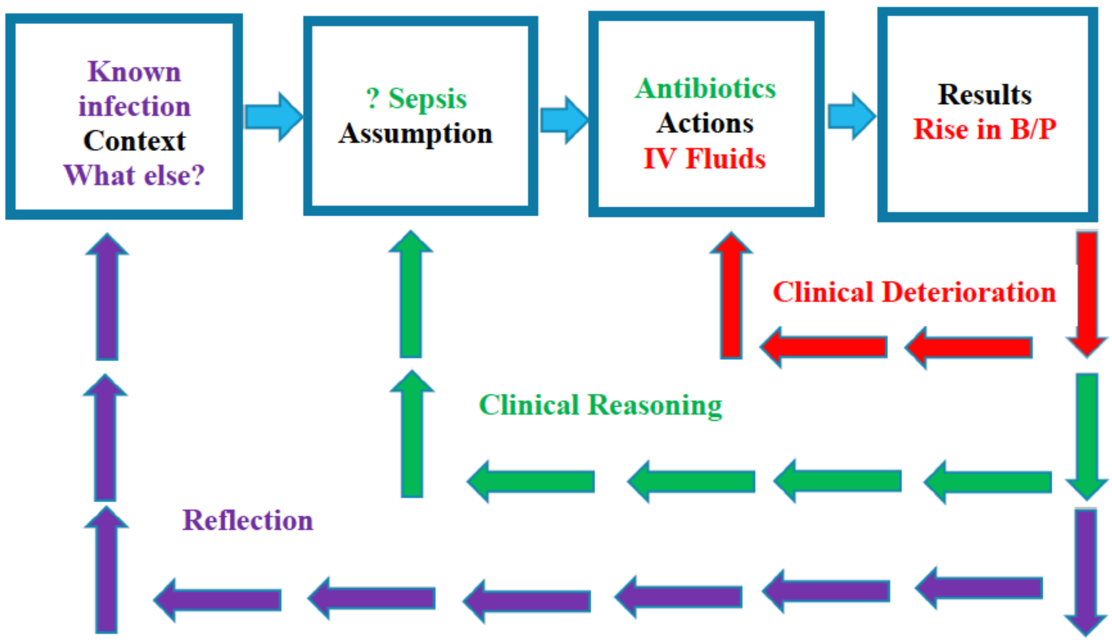

Figure 6. Loop 3. Adapted from Thorsten's Wiki as cited in Organisational Learning, 2014).

Note. IV = Intravenous B/P = Blood pressure

As expertise develops, application of procedural knowledge to address Loop 1 overlaps with diagnostic reasoning strategies in Loop 2 as experienced clinicians are able to prioritise care appropriately and manage more than one thing at a time. Metacognition and reflection both during and after the case contributes to Loop 3 learning. The development of expertise is diagrammatically represented in Figures 7, 8, and 9, illustrating how thinking in all three cognitive loops merges over time as clinicians become more experienced at dealing with clinical deterioration.

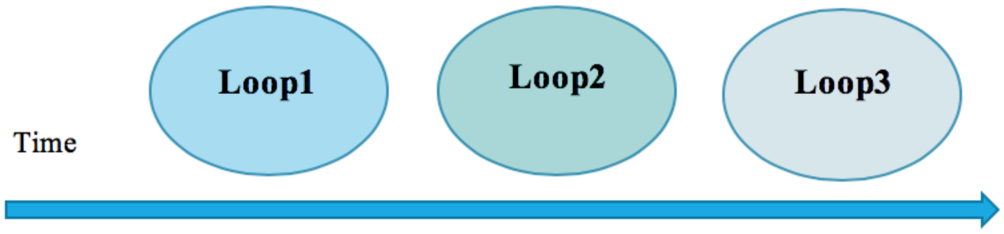

Figure 7. Novice practice.

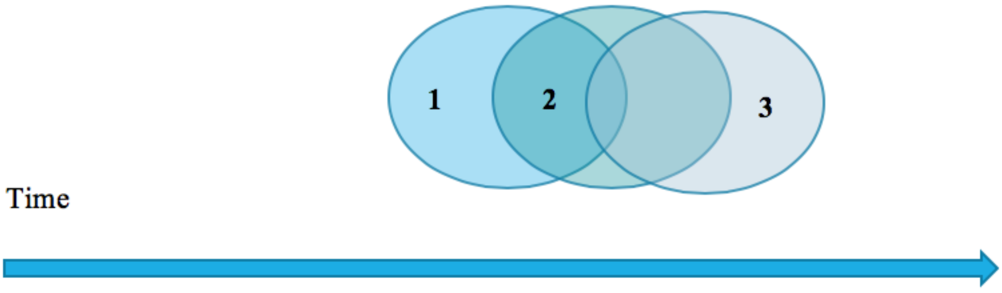

Figure 8. Developing expertise.

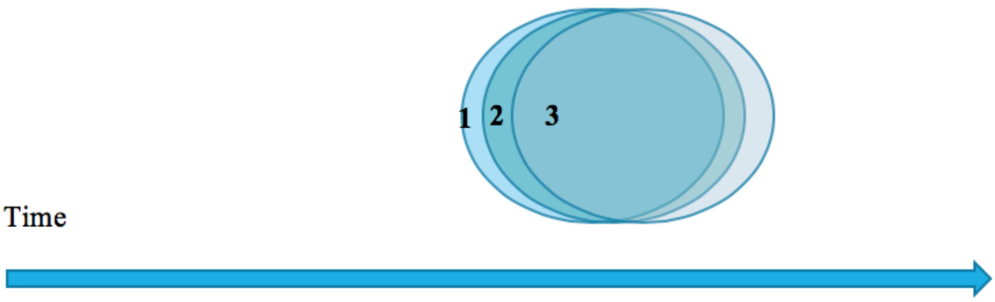

Figure 9. Expert practice.

In Figure 7, this diagrammatical representation displays the artificial separating out of the normally parallel processes that students observe experienced clinicians using in real clinical practice. Repeatedly and strictly adhering to the rules of patient stabilisation using the DRSABCDEFG framework ensures that nothing important is overlooked during this process. Only when this cycle has been completed are students permitted to enter the second loop where diagnosis and management become the priority. Obviously, rigid adherence to this process is ineffective in the long term, but with repeated practice and appropriate coaching, clinical expertise develops to the point where actions become automated and processes occur in parallel. The emphasis here is linking textbook knowledge to the clinical presentation. The third loop is finally entered at both the completion of the case and beyond during a reflective period that addresses the learning that occurred during the experience, in particular what clinical knowledge has developed from the clinical experience. Expert practice, as represented in Figure 9, when all processes occur simultaneously, is often what novice students observe in real clinical encounters but usually without the benefit of having observed or learnt them as separate entities.

Central to the success of triple-loop learning as a conceptual framework for instructional design in simulation is the ability to remove time constraints from the process. For example, unlike in the real world, in simulation it does not matter how long it takes to complete the first loop as long as all steps within it are adhered to and understood. Removing time pressure at this stage of learning removes any extraneous cognitive load usually experienced in stressful and dynamic situations and allows for the completion of each loop in a non-time pressured way prior to moving on.

In the context of this research, the skills required to address Loop 1 issues are considered 'lower-level' skills in that they are an automatic response to a given situation. Loop 2 and 3 skills are considered 'higher-level' thinking skills that impose a higher cognitive load. LaBerge and Samuels (1974) suggest that automatisation of lower-level skills frees up attentional capacity required to execute higher-level skills. As such, the implicit and automated qualities of Loop 1 skills and the conscious processing qualities of Loop 2 skills can be likened to similar aspects of System 1 and 2 thinking in dual-processing theory discussed earlier in this chapter (section 1.3.1).

1.4.5 A model of skill acquisition

The application of knowledge in clinical settings is a very different strategy to that which has been previously utilised by students in medical school where clinical reasoning has been assessed using written exams, multiple-choice questions, script concordance test cases, and performance-based test stations (Ilgen et al., 2012; Orrock, Grace, Vaughan, & Coutts, 2014). Literature and research on the progress of medical student learning focuses heavily on their cognitive abilities, in particular their ability to think critically and to develop strong reasoning skills. There is very little to be found in the literature on the practical application of these skills in a clinical context. One explanation for this is that the clinical component of the medical curriculum does not include direct patient management.

It is only in synthetic learning environments such as simulation that this aspect of clinical practice can be experienced. Recognition of this state of affairs does not mean that this aspect of practice is undervalued or neglected during medical training, but that opportunities for direct patient contact are limited for safety and ethical reasons. As a result, the application and further development of this expertise occurs later on after graduation during internship. This may be somewhat surprising for lay people to understand as the traditional view is one of graduating doctors being 'fully trained'. However, the reality is that the intern years are also considered a component of basic training.

Therefore, in order to explore the development of expertise in clinical practice, one needs to draw on literature outside of medicine. The Dreyfus and Dreyfus model, 'A five-stage model of the mental activities involved in directed skill acquisition' introduced in 1980 as a step-wise learning progression has been refined over the years and is considered a useful framework for understanding the development of expertise. (Dreyfus, 2004; Dreyfus & Dreyfus, 1980) It has provided a solid foundation for investigation of skill acquisition across other disciplines. In particular, it informed Benner's (1984) seminal work in nursing around knowledge embedded in clinical practice.

In particular, the transformation from novice to advanced beginner (Benner, 1984) requires clinical experiences that change the learners' capacity to perform in complex situations. Berragan (2013) posits that learning the skills of practice include learning new perceptual skills and that these new insights can be used to notice and interpret clinical signs that were previously unrecognised. These developing skills form a 'habitus of skills, perceptual acuity and action', which ultimately develop into a skilled, incorporated practice (Bourdieu, 1990, p. 116). Beckett and Hager (2002) refer to this as 'know-how' or 'knowing what to do in practice' (p. 37). Benner (1984) concurred with this sentiment by arguing that skilled know-how or practical knowledge is a form of knowledge, not just the application of it. Furthermore, knowledge is developed through interacting with others in collaborative teamwork. This again focuses the discussion on decision-making in and of itself as a critical skill requiring adaptive expertise. For the participants of this study, the data analysis will identify elements in cognition that support a judgement about their development along this continuum of expertise, as illustrated in Figure 10.

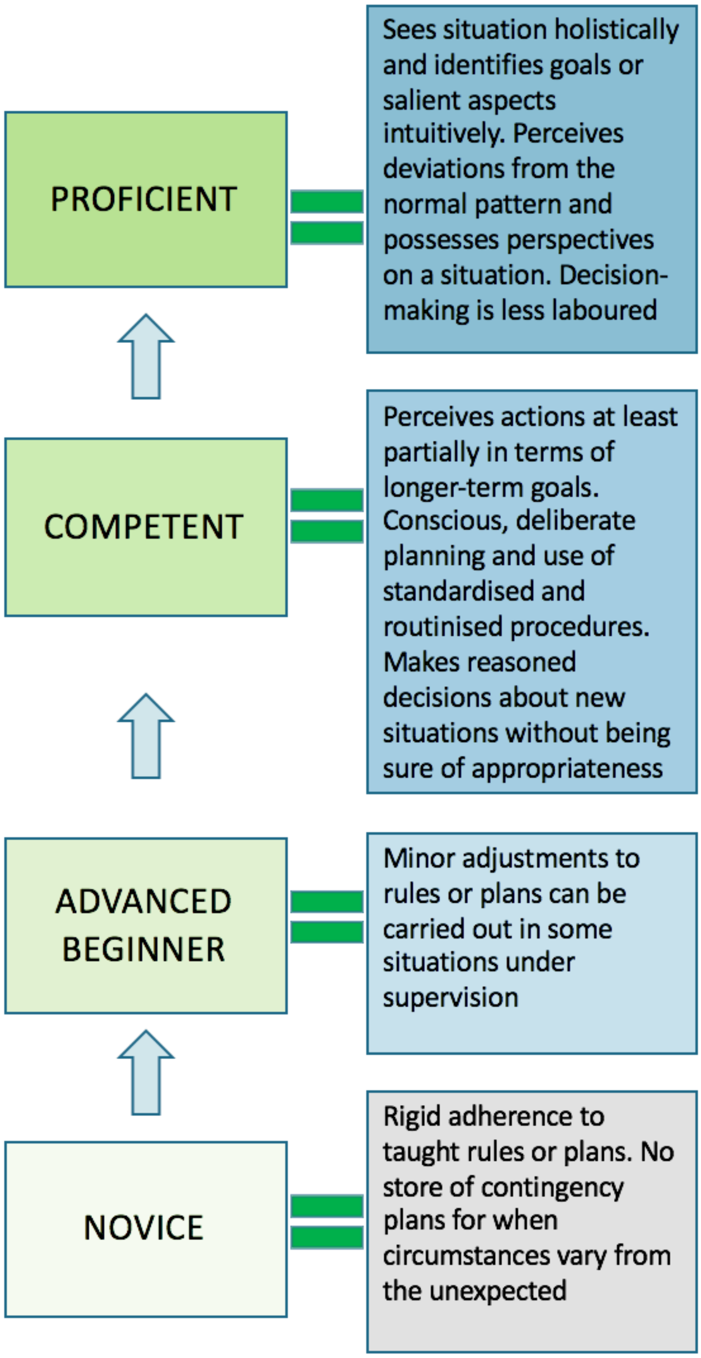

Figure 10. A model of skill acquisition (Adapted from Dreyfus & Dreyfus, 1980).

1.5 The need for training

1.5.1 Clinical reasoning

Despite its importance, medical education at present has built an environment that does not always actively promote development of clinical reasoning (Connor et al., 2019). Part of this is due to the belief that clinical reasoning will be acquired on its own over time with practice and an accumulation of knowledge (Tay et al., 2016). According to Ryan and Higgs (2008), in many health professions courses the goal of developing clinical reasoning skills is made explicit, but there is a lack of evidence in curricula about how this goal will be achieved. They further argue that there is a need to promote a more sophisticated reasoning process than currently exists to better suit the complexities of modern-day practice. As previously stated in this chapter, observational learning of clinical reasoning in clinical practice does not usually make expert reasoning processes explicit to the learner. Traditional ward-based teaching formats have been unsuccessful in providing insights to learners in how diagnostic decisions are made (Ryan & Higgs, 2008). Additionally, expert clinicians using mainly System 1 thinking strategies appear to learners to be using intuition rather than the more systematic approach of data collection, problem presentation, and hypotheses generation taught to medical students. For medical students to develop expert clinical reasoning skills, Connor et al. (2019) advise that they need ‘longitudinal instruction, practice, coaching and formative feedback’ (p. 3/51).

1.5.2 Clinical deterioration

As previously discussed, there is clearly a need for explicit training in clinical deterioration teamwork and taskwork skills for junior doctors. It is recommended that training in such skills needs to be undertaken during medical school (Callaghan et al., 2018). Despite their best intentions, authorities remain challenged as to how best to address this issue. Recognising and responding to acute deterioration (RRAD) in health care is Standard 8 (previously 9) of the National Safety and Quality Standards (NSQHS; Australian Commission on Safety and Quality in Health Care). The Australian Commission on Safety and Quality in Health Care (2014) state the following with regard to training for clinical deterioration:

> *Educating and training clinicians in the essential skills for recognising and responding to clinical deterioration is a necessary task for the delivery of safe care.... Currently*

> *there is no agreed approach about how best to provide training that meets these objectives or how to describe and assess the minimum standard for competence. Approaches to training and educating clinicians about clinical deterioration vary according to professional group and speciality, level of training and location. There appear to be few cases where there are clear and consistent requirements regarding the minimum level of competence that is required in order to provide safe and effective care to patients who deteriorate in acute settings. (pp. 5,7)*

Despite the introduction of METs and RRTs to address clinical deterioration, it is the on-call junior doctor who is often first sought to attend in the early stages of clinical deterioration. With regard to training medical students in clinical deterioration, the commission further states that

> *Since 2010, Medical Deans Australia and New Zealand (MDANZ) have been conducting a three stage competencies project to identify, describe and benchmark the competencies, diagnostic and procedural skills, and assessment standards for undergraduate medical education. ... For example, medical graduates are expected to be able to recognise serious illness and perform common emergency and life-saving procedures, including caring for unconscious patients and providing cardiopulmonary resuscitation. (p. 9)*

The literature pertaining to medical student learning of clinical deterioration skills, particularly in simulation, is vast. However, the majority of programs developed to teach such skills are massed learning short courses of less than four hours (Hogg & Miller, 2016; Liaw, Rethans, Scherpbier, & Piyanee, 2011; Smith & Poplett, 2004). Additionally, outcome measures are most often confidence and/or satisfaction ratings rather than skill retention studies (Seaton et al., 2019).

1.5.2.1 Taskwork

Suboptimal training of undergraduates and junior doctors in acute care skills remains a major problem. A large systematic literature review found that junior doctors lacked competence in all aspects of acute patient care, including the basic task of recognition and management of clinical deterioration (Brennan et al., 2010). That review also found that junior doctors felt ill-equipped to perform some acute care skills up to three years after graduating (Brennan et al., 2010).

Further, Smith, Perkins, Bullock & Bion, (2007) found that junior doctors had difficulty applying a structured approach to patient assessment. Tallentire et al. (2015) posit that systematic approaches can make task prioritisation easier. However, in times of acute stress, a high level of familiarity with these techniques is required to retrieve and apply them. For novice learners, whose biomedical knowledge is often learnt and stored outside a clinical context, memory recall within a clinical context can be difficult as the relevant neural connections have not been made (Bergman et al., 2015). Tallentire et al. (2015) go on to suggest that undergraduate medical training programs could address this issue by facilitating the repeated practice of basic patient assessments in a variety of contexts to highlight the transferability of those frameworks. Callaghan et al. (2018) concluded that preparation of junior doctors in the recognition and management of the deteriorating patient is influenced by effective simulation education and clinical experiential exposure over time.

Individual clinical schools within hospitals are responsible for teaching clinical deterioration skills to medical students. There is no standardised curriculum or assessment standard associated with this component of the curriculum. A variety of formats are utilised to deliver clinical deterioration teaching including lectures and simulation-based learning opportunities. The majority of these sessions are taught as massed short-course learning events in the final year of training or are taught infrequently over a longer period of time (personal knowledge).

1.5.2.2 Teamwork

Teamwork training has the capacity to significantly reduce medical errors and therefore improve patient outcomes (Freytag, Stroben, Hautz, Eisenmann & Kämmer, 2017). Currently, medical education focuses almost exclusively on the acquisition of knowledge and technical skills with minimal emphasis on teamwork or leadership skills required to effectively lead teams (Leonard, Frankel, & Knight, 2013). Simulations focused on teamwork and communication skills are considered crucial for improving patient safety (Birnbach & Salas, 2008; Kuehster & Hall, 2010; Smith, Siassakos, Crofts & Draycott, 2013).

For many years, a range of simulation techniques and technologies have been used to train teamwork-related knowledge, skills, behaviours and attitudes (Beaubien & Baker, 2004). Team training works when there are opportunities for the deliberate and repeated practice of teamwork skills in a simulation environment (McGaghie, Issenberg, Petrusa, & Scalese, 2010). Team training provides opportunities for groups of students to work and learn together, not only to develop requisite taskwork skills but also shared understanding of the teamwork, taskwork, equipment, and patterns of communication. Like all skills, teamwork competencies decay without regular reinforcement and practice. According to Gaba (2006, par 4), long-term repetitive training and practice is required to influence teamwork behaviours permanently. Furthermore, he recommends simulation-based teamwork training because it

- *involves participants in clinically challenging situations that link directly to their previous work experience;*
- *provides scenarios of known and specific challenge to teamwork skills;*
- *provides opportunities for cross-role understanding and even cross-training and practice in the work of different roles;*
- *facilitates reflection on practice by the team through a shared review of what transpired in the simulation scenario; and*
- *provides scheduled time for such exercises, with specially trained teaching faculty.*

Additionally, team cognition plays a critical role in team effectiveness and performance outcomes (Salas & Fiore, 2004). Simulation-based training provides experiential opportunities for development of team cognition that may build upon, or even replace, actual clinical experience (Fernandez et al., 2017). Finally, in their recent integrative review Callaghan et al. (2018) found that improved models of undergraduate and postgraduate educational simulations would contribute to improving both taskwork and teamwork skills for the management of the deteriorating patient.

1.5.3 Cognitive components of training

Training is a learning activity aimed at modifying or developing knowledge, skill, or attitudes, resulting in the learner acquiring abilities that can be used to perform a given task (Buckley & Cape, 2009). Training often implies that skill mastery is attained through repetition with very little cognitive input (Beckett & Hager, 2002). The concept of training is different to the concept of education, although there are overlapping principles between the two (McDaniel, 2012). Within medicine, the term 'training' usually refers to an overall concept of progressing through a prescribed course: 'training to be a doctor', 'physician training', 'surgical training', and so on. However, the majority of the literature pertaining to training in medicine refers to a narrower context of learning procedural skills such as intravenous cannulation (Kneebone & Baillie, 2008). From the perspective of simulation, this is also the case, with 'training' usually referring to the use of part-task trainers to learn and practise procedural skills. Team training also features heavily within simulation, but very little of this occurs during medical school.

Bourne and Healy (2012, p. 2) describe three cognitive components of training:

- The acquisition of knowledge and skills (declarative and procedural)
- Retention of learning over time
- Transfer of skills to new contexts.

1.5.3.1 Acquisition

Despite the complexity of a given skill, there are three stages in the development of automated skills (Anderson, 1982). First, in the *declarative* stage (also known as the cognitive stage), there are high cognitive demands on the learners as they develop a conceptual understanding of the task. Learning is slow and prone to error. Second, in the *knowledge compilation* phase (also known as the associative phase), there is further developing and refining of the stimulus-response pairings necessary for successful performance. Individual steps are 'chunked' or combined into larger units. Last, in the *procedural* or *autonomous* stage, the learner requires little cognitive effort as he or she progresses towards automaticity (Anderson, 1982; see also Heggestad, Clegg, Goh & Gutzwiller, 2102). Automaticity is a mechanism that allows the bypassing of working memory limits (Clark et al., 2006).

1.5.3.2 Retention

In terms of skills acquisition, especially if there is a threat that they might not be used for extended periods of time, retention is of the utmost importance (Kluge, 2014). In relation to retention, Bjork and Bjork's (1992) theory of disuse describes how *storage* strength (how well something is learned) and *retrieval* strength (recall in response to a cue) are required for retention. According to Bjork (2011), forgetting is due to retrieval capacity rather than storage capacity. Additionally, the storage strength of an item increases as an 'accumulation of study and recall opportunities' (Kluge, 2014, p. 138). Once acquired, storage strength is never lost; however, non-use decreases retrieval strength (Bjork & Bjork, 1992). As a result, storage strength improves the gain and prevents the loss of retrieval strength (Bjork & Bjork, 1992).

1.5.3.3 Transfer

The real-world application of skills and knowledge learnt in training is referred to as transfer (Alklind Taylor, 2014). 'Near' transfer occurs when skills are applied in settings familiar to which they were learnt. Application of those same skills to make sense of an unfamiliar context is ‘far’ transfer (Clark et al., 2006). Transfer is dependent on familiar cues prompting retrieval of schema from long-term memory. Kluge (2014) refers to this as ‘instance similarity’ (p. 143). Within simulation, the literature abounds with opinions on the link between transfer of learning from the simulation environment and simulation fidelity. There is much dispute in the literature about types of fidelity and their links to transfer of learning from simulation to the real world. Despite the high face validity of the notion that high fidelity equates to increased transfer of learning, the evidence to support that theory is tenuous (Hamstra, Brydges, Hatala, Zendejas, & Cook, 2014). In this study, the concept of fidelity is not discussed at length due to a preference for the notion that student *engagement* is dependent on a number of factors. These include cognitive load management, awareness of the learner zones of proximal development, appropriate in-simulation coaching support, maintaining a state of ‘flow’, and the social nature of the learning environment, all of which are discussed later in this chapter.

1.6 Simulation-based learning

In order to develop a simulation curriculum, including appropriate instructional design elements, which meets the learning requirements of medical students in equipping them with the knowledge and skills to manage clinical reasoning and clinical deterioration, it is first necessary to look at contemporary simulation practices. The next section will discuss learning theories that underpin simulation-based learning followed by describing generic and specific simulation styles and their relationship to medical student education.

1.6.1 Learning theory

There are many theories that explain how learning occurs in simulation. McGaghie and Harris (2018) state that simulation-based learning in health professions education ‘sits within a broader historical context of learning grounded in workplace apprenticeship experiences’ (p. S16). Among its many uses, simulation-based learning replaces and complements aspects of situated learning that occurs in clinical settings as learning is related to the authentic skills of clinical practice. Simulation experiences that reflect the contextual realities of clinical practice will match the simulation designer’s or facilitator’s view of how learning is enabled. Historically, foundational learning theories related to simulation-based learning have predominantly included behaviourism, constructivism, and sociocultural theories (Bearman, Nestel, & McNaughton, 2017; McGaghie & Harris, 2018). As such, learning ranges from a focus of observable behavioural changes through to an emphasis on the learner within a social context in which the learning occurs.

1.6.1.1 Behaviourism

Behaviourism views learning as a desired change in behaviour as a result of reward and encouragement for correct behavioural changes based on repetition, feedback, and correction (Skinner, 1976; Taylor & Hamdy, 2013; Torre, Daley, Sebastian, & Elnicki, 2006). Behaviourism is less concerned with higher order metacognition and more concerned with how the right outcome can be achieved and repeated through conditioning (McGaghie & Harris, 2018). In simulation, this approach often underpins the teaching of psychomotor skills such as surgical techniques. However, the focus for this study is on problem-solving skills required for acute patient management skills, which aligns more closely with constructivist learning theory.

1.6.1.2 Constructivism

Constructivists view learning as being actively constructed by the learner. Constructivist theory explains how new understanding develops by building on an individual's existing understanding (Knowles, Holton, & Swanson, 2005). In medicine, common constructivist approaches are problem-based learning and case-based learning where a facilitator guides the development of content knowledge, critical thinking skills, and self-directed learning skills to solve a particular problem (Barrows & Tamblyn, 1980). Traditional facilitation in this context is described as 'minimally guided'. From a constructivist perspective, minimal guidance is considered crucial for learners to construct knowledge for themselves (Bruner, 1961). However, Kirschner, Sweller and Clark (2006b) advise that due to the high cognitive demands placed on the learner in this setting, guided learning rather than minimal guidance is recommended to prevent high extraneous cognitive load. This is especially relevant in problem-based and case-based simulation design where the realism of the situation and enactment of the case add extra cognitive burden to the situation for novice learners.

As there are elements of both problem-based and case-based learning in medical student simulations, constructivism is a useful theory to incorporate into simulation design. Due to the social environment and the complex nature of the teaching space, constructivism lends itself more to the whole process of simulation. Constructivist approaches to learning led to the development of a theory of cognitive apprenticeship (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989). Cognitive apprenticeship goes beyond the traditional apprenticeship in that the learning activity is modelled within the context of real-world situations and emphasises cognitive skills rather than psychomotor skills. Although considered constructivist, the focus in cognitive apprenticeship is on the provision of learning support through a variety of techniques that guide learning. In particular, scaffolding is considered important, especially for novice learners. Cognitive apprenticeship is utilised in this study as the theoretical foundation of the new role of in-game coach and is discussed in more detail later in the chapter.

1.6.1.3 Sociocultural theories

For practiced-based professions such as medicine, learning is more meaningful if situated within authentic environments (Conn, Lake, McColl, Bilszta, & Woodward-Kron, 2012). Sociocultural learning theories, in particular situated learning and communities of practice (Lave & Wenger, 1991), offer a useful theoretical perspective for this study. The overall concepts of a community of practice are ‘activity, meaning, cognition, learning, and knowing’ (Lave & Wenger, 1991, p. 50). Learning is viewed as being intimately linked to context and occurring through social participation and engagement in the activities of the community (Chen & ten Cate, 2018). Situated learning is based on Vygotsky’s (1978) social development theory and has a focus on learning occurring through participation in communities of practice. Novices learn the practices of the community by participating alongside more experienced participants in legitimate peripheral participation (Lave & Wenger, 1991). As expertise develops, learners gain legitimate entry to a community of practice in an apprenticeship style of learning. Expanding this theme, rather than an ‘immersion’ style of traditional apprenticeship in which learning by experience is basically achieved through opportunistic exposure to learning, the cognitive apprenticeship model is based on higher order problem-solving strategies and skills modelled by an expert in order to make thinking visible (Collins et al., 1989). Simulation provides opportunities to add sequence and structure to workplace learning activities supported by guided instruction, in which expert thinking is made visible to the learners. Additionally, the simulated clinical environment and the activities contained within it afford learners discipline-specific opportunities to solve complex problems through thinking, acting, and interacting with others. Shaffer (2006) describes this as the *epistemic frame* of a profession enabling learners to develop domain-specific expertise under realistic constraints. Included in this frame are a collection of skills, knowledge, identity, values, and epistemology that are interconnected and become internalised through training and immersion in realistic environments (Shaffer, 2006, p. 474).

Within simulation, the concept of an epistemic frame can be applied with the coach as the 'expert' providing guidance and modelling practices within a community of practice. Appropriate guidance required to increase learners' participation within that community as they progress towards becoming a full member requires an awareness and monitoring of the learner's zone of proximal development. This is based on a second aspect of Vygotsky's (1978) theory that the potential for cognitive development is limited to a zone of proximal development. Broadly speaking, the zone of proximal development is the difference between what a learner can do without assistance or guidance and what they cannot do (Chaiklin, 2003). The zone of proximal development is discussed in more detail in the context of simulation design later in the chapter.

1.6.1.4 Instance-based theory

A theory that relates to skills acquisition, retention, and transfer in situations that require dynamic decision-making is Gonzalez, Lerch and Lebiere's (2013) instance-based learning theory. This theory suggests that in situations of dynamic decision-making people learn through an accumulation of instances (Kluge, 2014). According to Kluge (2014), instances are 'a set of environmental cues (the situation), a set of actions applicable to the situation (decisions) and an evaluation of the appropriateness of that decision in that particular situation (the utility)' (p. 110). Dynamic decision-making is usually situated within the context of complex tasks represented in serious games and screen-based simulations (Gonzalez, Fakhari & Busemeyer, 2017). Although the detail differs, there are close relationships between that environment and the dynamic decision-making processes in complex clinical deterioration simulations. Gonzalez et al. (2017) describes dynamic decisions as those that *involve a sequence of choices made in an environment that can change exogenously or as a function of previous choices and where decisions are sequentially linked to each other through their effects so that an action at a specific time directly or indirectly influences future actions. (p. 714)*

Gonzalez et al. (2003) further describe instance-based theory as a combination of processes such as the accumulation of examples in memory through repeated training, development of pattern recognition, critical thinking, and similarity-based retrieval. This theory underpins the distributed nature of the simulation program and its focus on schema development and pattern recognition to support dynamic decision-making in the setting of clinical deterioration. Further, the problem-solving component supports learning in clinical reasoning.

Unlike behavioural and constructivist learning theories, and to a lesser extent sociocultural learning theory, instance-based learning theory with its focus on dynamic decision-making embedded in a team task underpins the design of activities aimed at the development of taskwork and teamwork skills. Table 4 summarises the learning theories and how they relate to simulation and to this study.

Table 4. Learning theory, associated simulation style, and relevance to this study

Learning theory	Simulation style	Relevance to this study
Behaviourism	Psychomotor skills training	Not applicable
Constructivism	Individual or team-based immersive simulations	Relevant due to the learner constructing new meaning through experience and interaction with others; however, minimal guidance is replaced with guided instructional support
Sociocultural	Team-based immersive case-based simulations	Highly relevant due to learning being embedded in the social context of practice
Instance based	Repeated episodes of situations requiring problem-solving and decision-making	Highly relevant due to the nature of the simulations requiring dynamic decision-making to implement patient management strategies

As discussed, behaviourist simulations are usually designed to teach psychomotor skills such as surgical procedures on part-task trainers. A focus on repeated practice to reach a prescribed standard is a feature. The facilitator either corrects performance in action or gives feedback on action. Behaviourism's focus on skill repetition and its lack of attention to problem-solving and critical thinking makes it a less suitable theory for this study. In contrast, constructivist style simulations take the form of an immersive patient-based simulation for individual clinicians or for teams either in real time or in a pause-and-discuss style. Either way, the facilitator or debriefer allows the simulation to unfold as a case-based presentation of a particular illness that the learners need to diagnose and treat through the construction of meaning. Sociocultural team-based simulations, such as those that form the basis of this study, are based on a cognitive apprenticeship framework whereby guided instruction is provided in action with the coach acting as a team member to support learning. Scaffolding is a particular focus on this style of simulation, with the coach actively monitoring where learners are positioned within their zone of proximal development in order to adjust the required support. Instance-based theory underpins the dynamic decision-making component of simulations. Again, the provision of a simulation coach supports learners' decisions 'in the moment', which allows the simulation to progress in the right direction. Although quite a few theories have been described here, the complex nature of the simulation environment requires a number of theories as a foundational basis. The theories described in this section in relation to simulation-based learning are not exhaustive but each one has been considered for its usefulness in this study.

1.7 Simulation and training

During medical training, many students perceive a lack of emphasis on patient management as compared with making a diagnosis (Sefton et al., 2008). It could be argued that medical students do not actually engage in legitimate peripheral participation within their community of practice (Lave & Wenger, 1991), as they are almost always observers or bystanders rather than actual participants in most of the clinical activities they encounter. Though the detail differs slightly, their role is more akin to one of 'marginal participation' (Wenger, 1998, p 164) until they graduate. The resultant transition from student to doctor and the application of knowledge to practice is therefore often a difficult process (Yardley et al., 2018). Simulation can replace clinical experiences to ensure the required diversity of exposure to a range of clinical cases. Simulation also offers a bridge between academic and clinical learning environments that provides structured and sequenced learning opportunities that cannot always be organised or provided in clinical settings.

Many examples of the use of simulation in medical student education exist in the literature. These include content-specific simulations linked to a single subject, such as anaesthesia, trauma, anatomy and physiology, obstetrics and life support, clinical deterioration short courses, interprofessional learning, and psychomotor skills acquisition (Lipps, Bhandary, & Meyers, 2017). According to Fraser, Ayres, and Sweller (2015), simulation-based education is an effective and important teaching technique for medical educators, but very little research about how to optimise training with simulators exists. They claim that it is often difficult to generalise results from research in instructional design aspects of simulation because of the range of learners, teaching methods, and rapidly changing simulation technologies. Many studies identify improved confidence in overall performance and high satisfaction with simulation learning experiences, but again there is very little evidence of long-term retention of knowledge and skills (Cook et al., 2013). It is acknowledged by the healthcare simulation community that research needs to move beyond basic satisfaction and confidence surveys to a deeper analysis of how simulation influences practice (McGaghie, Issenberg, Cohen, Barsuk & Wayne, 2011; McGaghie et al., 2010).

1.7.1 Simulation styles

From a design perspective, two styles of healthcare simulation dominate the landscape:

1. Fully immersive simulations – *single participant.* Individual clinicians – usually referred to as the *'hot seat'* participant – undertake real-time (or fully immersive) simulation activities in order to practise the management of rare, life-threatening events. They bring with them the skills, knowledge, and attributes to manage such a situation but are usually lacking in the opportunity, experience, and practice to do so effectively. The situations the clinicians encounter in these simulations are thus dynamic, time pressured, and potentially stressful. The objective of the session is to improve clinical practice and, in some settings, to provide 'stress inoculation' opportunities. Stress inoculation is when participants experience stress during a simulated clinical case that closely mimics the urgency of a real-world setting. In theory, they then become inoculated to this stress and are more able to deal with it in the clinical setting (DeMaria & Levine, 2013).
2. Fully immersive simulations – *team training***.** This simulation style is designed for teams of clinicians, usually *interprofessional,* to practise working together *as a team*

in managing a medical emergency. Issues such as leadership, communication, situation awareness, mental models, and teamwork are addressed with the overall objective of improving patient safety through improved teamwork. An example of this would be team training for operating room staff, who include medical, nursing, and technical personnel.

Both styles of simulation are conducted in real time under the high-stress and high-demand conditions of real clinical practice as participants have brought with them the knowledge and skills to progress through the case uninterrupted. For both of these simulation styles a post-hoc debriefing is conducted at the completion of the scenario. The debriefing is often 'video assisted' if the simulation scenario was videotaped.

Debriefing assumes 'that people make sense of external stimuli through their own frames of reference and that these frames become the basis for subsequent action' (Rudolph, Simon, Rivard, Dufresne, & Raemer, 2007, p. 363). The debriefing explores frames, actions, and results, and the building of new frames for use in future actions. Rudolph et al. (2007) suggest that this collaborative exploration is when the learning occurs based on the formation of a joint understanding of improved frames and actions. Both of these simulation styles are unsuitable for novice learners who have not yet developed frames of clinical practice and would be unable to progress through the case unaided.

A less utilised form of team-based simulations also exists that are designed with more novice learners in mind. In this case, a facilitator in the simulation room utilises a pause-and-discuss simulation style, which is a variation of a real-time simulation but includes pauses, or interruptions, at salient points to suspend the simulation for reflection and discussion. This allows facilitators to use unscripted questions and discussion points to assist students to develop a shared interpretation of the event during the timeout phase. This style allows for a staggered progression through the scenario, enabling learners to overcome any hurdles that would have otherwise halted their progression to completion.

Despite these well-entrenched simulation design styles, there is little indication in the literature of the best way to deliver simulation-based learning to medical students. Similar benefits and drawbacks are described for both real-time and interrupted simulations. One study compared post-simulation debriefing with in-simulation debriefing in medical student simulations. (Heukelom, Begaz, & Treat, 2010). In this study, the indication for the facilitator to call a 'timeout' was a 30-second pause in the simulation action. One possible implication of this time-based rule is recurring and multiple interruptions to scenario flow. The researchers do not state how often the scenario was suspended. Additionally, although giving feedback in real time through pause-and-discuss is helpful, there are concerns that repeated interruptions to the simulation may devalue the realism of the simulation and result in less effective learning (Doezema, & Sklar, 2002; McMullen et al., 2016).

There are two issues of concern in the aforementioned pause-and-discuss style of simulation commonly used in medical student education that require adaptation to better suit the learners' needs. First, the effect on learners of repeated interruptions to the simulation and, second, issues related to cognitive workload. Two conceptual frameworks are used to discuss these issues: cognitive load theory (Sweller, 1994), which is based on Vygotsky's (1978) zone of proximal development, and flow theory (Csikszentmihalyi, 1985).

1.7.2 The zone of proximal development

The zone of proximal development is a feature of Vygotsky's (1978) sociocultural theory of learning, discussed earlier in this chapter, which identifies a zone in which learners are situated in relation to their abilities. It is the difference between what a learner can achieve without assistance or guidance and what they can achieve with assistance (Harland, 2003). This is sometimes referred to as the 'sweet spot' (Le Bel, Ara, Tekian, & Cristancho, 2017).

The zone of proximal development needs to be identified and have learning opportunities constructed within it. This allows learners to complete tasks that they are not capable of doing on their own but can achieve with assistance from someone more knowledgeable (Wertsch, 1985). Learners are able to operate at a higher level than they could on their own, and this enables them to eventually perform independently at this level.

There is an increase in learning gain by providing learning environments that enable learners to perform more difficult tasks than would otherwise be possible (Wass &

Golding, 2014). The environment must be conducive for a particular kind of task. With support, this will allow learners to attempt much harder tasks and thus learn to do more than they could do in a less beneficial environment. Support for learners within their zone of proximal development occurs through scaffolding (Wood, Bruner, & Ross, 1976). Scaffolding is support, guidance, advice, prompts, directions, or resources a learner is given that enables them to complete the task (Davis & Miyake, 2004). Through the careful application and subsequent fading of scaffolding, the zone of proximal development reduces the developmental distance between coach and student (Chaiklin, 2003), as illustrated in Figure 11.

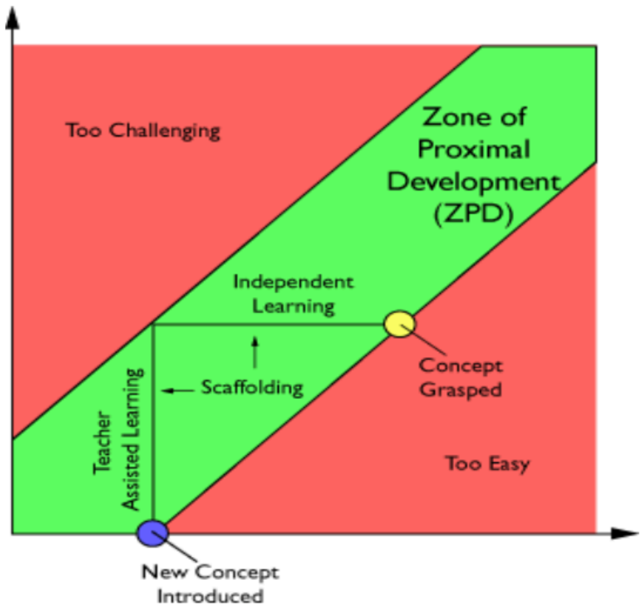

Figure 11. The zone of proximal development (Thissen, 2015).

While maximising learning within a learner's zone of proximal development, appropriate scaffolding techniques also ensure that cognitive load is managed through attention to the task complexity. As well as scaffolding being provided through coaching, other memory aids such as action cue posters, clinical protocols, and the use of mnemonics support learning.

1.7.3 Cognitive load

1.7.3.1 Working and long-term memory

From a psychological perspective, memory covers four important aspects of information processing: encoding, consolidation, storage, and retrieval (Tulving & Thomson, 1973).

All learning and activity rely on two of the memory systems: the partnership between long-term and working memory (Clark et al., 2006). Working memory is the ‘active partner’ with very little storage capacity, whereas long-term memory is the knowledge repository with a huge capacity for storage (Clark et al., 2006). Working memory processes information whereas long-term memory is inert (Clark & Lyons, 2011). Processing involves gathering information and organising it in relation to what is already known – encoding, storing, and retrieving (Sternberg & Sternberg, 2010). This new content is integrated into existing schema through ‘elaboration of information’ resulting in the encoding of new knowledge into long-term-memory, which eventually becomes the basis for transfer of learning (Clark et al., 2006). Piaget (1936) introduced the concept of schemata, which are abstract knowledge structures that organise vast amounts of information. Thoroughly processed and connected information becomes part of long-term memory, and when reactivated or retrieved becomes part of working memory (Jonides et al., 2008). This is called ‘activation of relevant pre-existing knowledge’ (Clark et al., 2006, p. 36). The virtual capacity of working memory increases as learners gain expertise and their schemas further develop in long-term memory (Clark et al., 2006). Consequently, they are able to process larger amounts of information.

Long-term memory can be further broken down into explicit (conscious) and implicit (unconscious) memory (Squire & Dede, 2015). Tulving (1972) further breaks down explicit memory into episodic (past experiences) and semantic (facts, knowledge) memory. Episodic memory is based on autobiographical experience and involves recall of a past event that is particular to a time and place (Conway, 2008; Tulving, 2002). According to Conway (2008), two or more conterminous episodic memory events provide the basis for schema development and theory formation. Repeated instance-based exposure to experiences is stored in episodic memory for later retrieval and underpins instance-based learning theory (Kluge, 2014).

1.7.3.2 Cognitive load theory

In complex cognitive environments it is necessary to support learning through the management of cognitive load. Cognitive load refers to the amount of effort being used in working memory. There are three main types that need to be balanced to maximise learning efficiency, as illustrated in Table 5.

Table 5. Cognitive load (Clark et al., 2006, p. 13)

Type of load	Definition	Characteristics	Approach to management
Intrinsic	Mental work imposed by the complexity of lesson content	Depends on the amount of element interactivity i.e. the number of elements requiring coordination	Decompose complex tasks into smaller tasks and distribute over several lessons
Germaine	Mental work imposed by instructional activities that benefit the learning goals	Relevant load that leads to better outcomes	Diversity of instructional techniques to outcomes that are applicable to a wide range of situations
Extraneous	Mental load imposed that is irrelevant to the learning goal	Wastes limited mental resources	Optimise various presentation modes Support learner attention Reduce amount of information to be processed in memory

The level of cognitive load depends on the interaction between the learning goal and its associated content, the learner's prior knowledge, and the instructional environment (de Jong, 2010; Sweller, Ayres, & Kalyuga, 2011). Matching the complexity of the learning goal to the learner's current knowledge is an example of an environment conceptually sitting within a learner's zone of proximal development. Cognitive load theory is based on the idea that working memory has limited capacity and can become overloaded under certain conditions such as learning new information (Krishner et al., 2006a; Miller, 1956). Thinking and learning is impaired once the capacity of working memory is outstripped (Miller, 1956).

Clark et al. (2006) state that 'cognitive load theory is a universal set of learning principles that are proven to result in efficient instructional environments as a consequence of leveraging human cognitive learning processes' (p. 7). The basic assumption is that when considered in educational instructional design, cognitive load theory emphasises definitive rather than minimal guidance during teaching and this is achieved through a variety of instructional techniques (Kirschner et al., 2006b). A learning framework grounded in cognitive load theory has been developed by Leppink and van den Heuval (2015), in which three dimensions of instructional design of learning activities are considered:

1. *Task fidelity addresses the realism of the encounter.* If the fidelity is too high, there is a risk of overwhelming the learner. An example of this would be a student pilot in a sophisticated airbus cockpit simulator for the first lesson.
2. *Task complexity considers the number of interacting elements in the activity.* The interelement activity must correlate to the learner's zone of proximal development in order for learning to occur. This not only keeps extraneous cognitive load to a minimum but ensures that intrinsic cognitive load is raised to the most beneficial level.
3. *Instructional support to provide learner support.* Instructional support that reduces extraneous cognitive load among novice learners may contribute to extraneous cognitive load among more proficient learners. Appropriate scaffolding and fading must be provided to support learning.

Within this framework, each of the three dimensions can be titrated to provide optimal load balance for the learners in any educational activity. Figure 12 visually represents the effect of cognitive load on memory and learning.

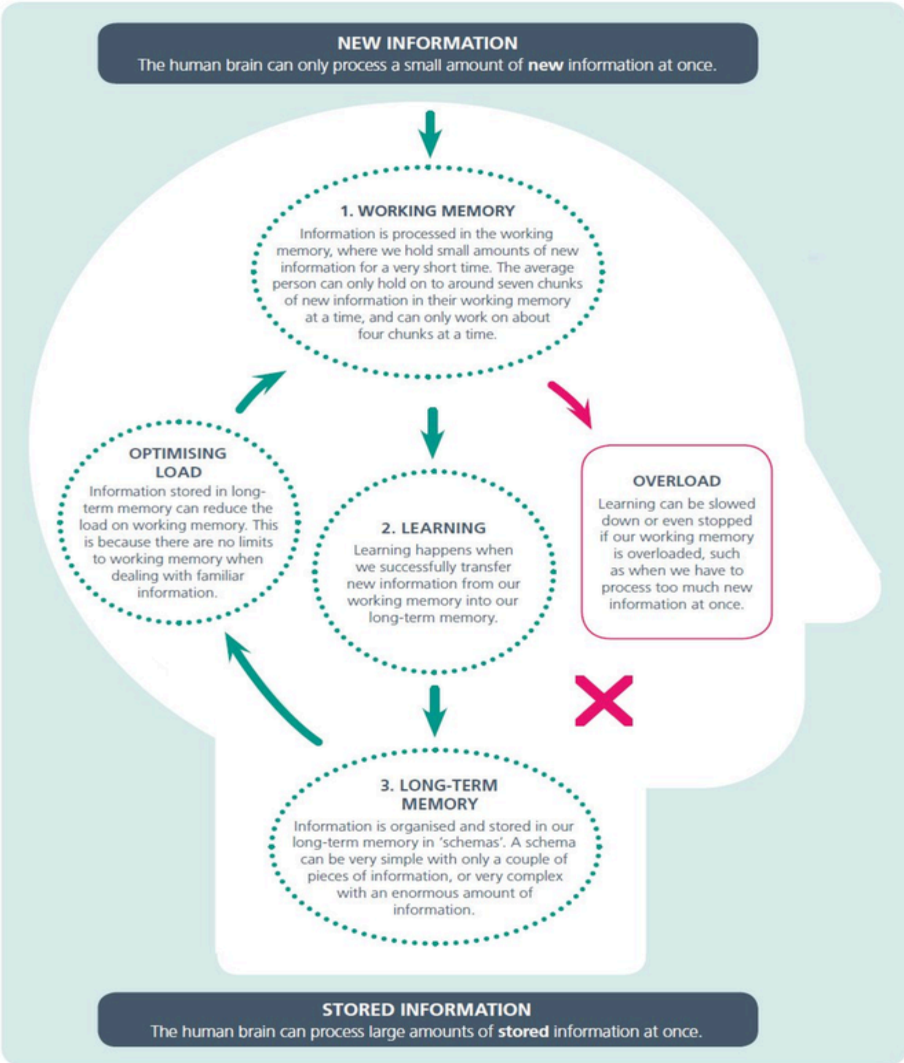

Figure 12. Learning and memory (DENSW, 2018).

1.7.3.3 Flow theory

Flow state is described as a feeling of energised focus and full immersion in the task resulting in a successful completion (Csikszentmihalyi, 2013). This ultimately leads to skill development and knowledge acquisition (Challco & Andrade, 2016). From the perspective of interruptions or suspensions to the simulation during a pause-and-discuss facilitation style, there is an interruption to flow when timeout is called. Engagement in flow depends on establishing a balance for learners between perceived learner capabilities and learner opportunities (Csikszentmihalyi, 1985). The balance is crucial – scaffolding must provide enough support to ensure a state of flow but not so much that it decreases the challenge for the learner. Achieving a state of flow is therefore dependent on the teacher's recognition of the learner's zone of proximal development.

Turkle (1984) describes the state of flow as 'holding power' over the learners. The nine elements of flow include challenge–skill balance, action–awareness merging, clear goals, unambiguous feedback, concentration on the task at hand, sense of control, loss of self-consciousness, transformation of time, and an autotelic (lack of external reward) experience (Csikszentmihalyi, 1975, pp. 35–54). Further, according to flow theory (Nakamura & Csikszentmihalyi, 2009), the following conditions must be satisfied to achieve flow:

1. Clear proximal goals in which expectations and rules are clearly discernible.
2. Direct and immediate feedback in which the successes and the failures of the task are apparent, so that behaviour can be adjusted as necessary.
3. Good balance between ability level and challenge (the ability–challenge balance).

Within flow, what happens at any moment is a response to what has just preceded it. Identifying these moments, and allowing flow to progress, thus becomes a crucial factor in the learners' achieving graded 'proximal goals' (Massimini & Delle Fave, 2000) and the subsequent intrinsic reward that this brings, fostering the continuity of the flow state. This resonates with van Merriënboer and Sweller's (2009) goal-free principle, whereby a set challenge to be reached is replaced with repeated graded challenges in order to reduce extraneous cognitive load. These intrinsic rewards lead students to seek out further flow experiences in order to engage in increasingly challenging activities. The successful implementation of such activities is therefore dependent on the simulation coach's awareness of the learners' zone of proximal development.

In summary, ideal conditions for learning are based on the application of zone of proximal development principles, supported through maintenance of flow and attention to cognitive load content, which need to be working in harmony in the setting of simulations. However, in sharp contrast to this, they are not reflected in pause-and-discuss simulations for novice learners. Despite a facilitator being present in the simulation room during pause-and-discuss simulations, the scenario unfolds in real time placing high demands on medical students' working memory. High element interactivity across the three domains of the simulation system, and the taskwork and teamwork required to address the patient problem, often results in learners reaching a point of cognitive overload by the time the simulation is paused. Indeed, the timeout is colloquially referred to as a 'life raft' for learners in simulation. Metaphorically speaking, the need for a life raft usually indicates a struggle for survival. High learner extraneous cognitive load coupled with a lengthy interruption to flow in order to correct student actions risks significantly inhibiting learning.

A reason for the use of pause-and-discuss simulations is that simulation-based education for medical students has organically grown out of more traditional uses such as medical registrar and consultant training without any consideration of how medical students differ in their knowledge construction and what they bring to simulation. In particular, one objective of real-time simulation for more senior clinicians is to provide 'stress inoculation' opportunities in which they practise performing tasks effectively under high-demand, high-stress situations (Groom & Hogan, 2006). However, if the stress is too high in the early phases of medical training, it may decrease the chances of successful performance and result in a negative training experience (Kluge, 2014) for the learners.

The motto for paediatric medicine is 'children are not small adults' in relation to their anatomy, physiology, and development, meaning that one cannot simply modify adult medical principles and make them fit a smaller version but must acknowledge what is unique about children (Moore, 1998). Similarly, medical students are not 'small doctors' and what makes them unique must be addressed when designing learning activities. They thus require a different pedagogical approach from that used for doctors in simulation-based learning. Instead of taking a real-time scenario and 'making it smaller' by debriefing it in segments, such as in the pause-and-discuss facilitation method, attention needs to be paid to an improved instructional design approach to better support learning for these students who are at an earlier stage of clinical development. If this is not addressed from an instructional design perspective, there is a risk of creating a 'simulation gap' (Bogost, 2007, p. 57). For these students that means that there is a difference between the learning objectives of the simulation and their experience of it. A common criticism of the use of simulation-based training refers to the fact that the pedagogy and theory behind simulation-based exercises are often not articulated (Rourke, Schmidt, & Garga, 2010). This results in educators potentially missing opportunities to implement effective instructional design elements (Cook et al., 2013). Christensen, Villanueva, and Grieve (2018) advise that simulation educators must now start thinking about developing curricula that is underpinned by theoretical frameworks that support learning.

1.8 Instructional design

1.8.1 Simulation and gaming

Turning now to domains outside of healthcare simulation, the world of serious gaming offers insights into the role of facilitator that are worthy of consideration in relation to instructional design in healthcare simulation. Simulation is defined as ‘a technique-not a technology- to replace or amplify real-patient experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner’ (Gaba, 2004, p. i2). Broadly speaking, both simulations and gaming encompass a range of methods, knowledge, practices, and theories, such as simulation, gaming, serious games, computer simulation, computerised simulation, modelling, agent-based modelling, virtual reality, virtual world, experiential learning, game theory, role-play, case study, and debriefing (Crookall, 2010). 'Serious gaming' is a term that is used frequently in the literature, however, there is a degree of uncertainty about it and what it encompasses, making it difficult to specify a comprehensive definition. In particular, epistemic games with their focus on enculturating learners into a professional community of practice through development of skills, knowledge, values, and behaviours of a specific profession, resonate with the objectives of clinical simulations (Schaffer, 2016). Marsh’s (2011) game spectrum classification has classical simulators for skills training at one end and games developed for fun and entertainment at the other. Somewhere in the middle are serious games and simulation games. The fluidity of this spectrum allows for a ‘sliding scale’ in which activities can be individually situated according to the particular learning objectives of the session and the amount of scaffolding required to support such activities.

Kirkley, Duffy, Kirkley, and Kremer’s (2011) five-stage learning cycle of serious gaming also resonates with the problem-based pedagogy of healthcare simulation:

1. Situation stage – the central problem is presented to the learner.
2. Issues identification stage – learners analyse the mission, develop hypotheses about how to address it, and what resources are available.
3. Inquiry stage – learners investigate, often in teams. Facilitator provides structure, scaffolding, guidance, and feedback.
4. Action stage – learners make recommendations to address the problem, develop rationales for recommendations, and begin to test their hypothesis.
5. Assessment stage – assessment, synthesis, and transfer of learning occur through some kind of debriefing activity.

Figures 13 and 14 represent Kirkley et al.'s (2011) five-stage cycle in serious gaming and its application to simulation planning.

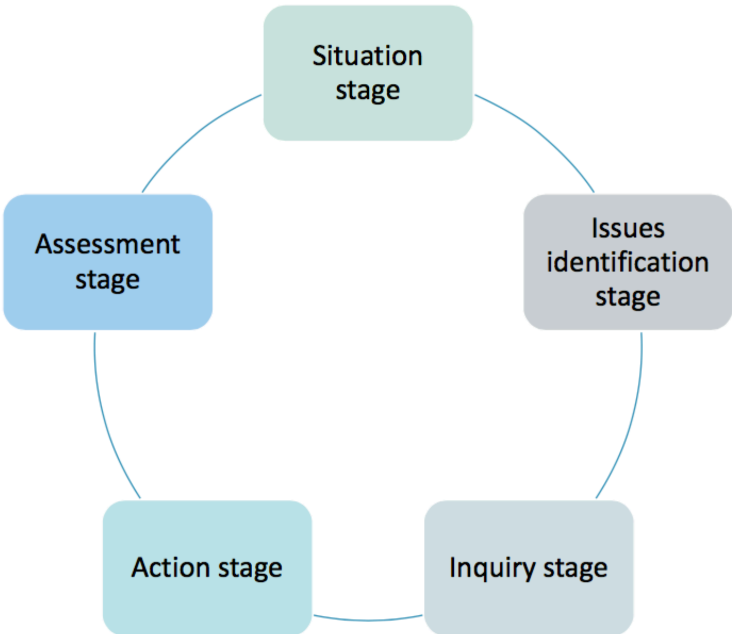

Figure 13. Five-stage cycle in serious gaming (Kirkley et al., 2011).

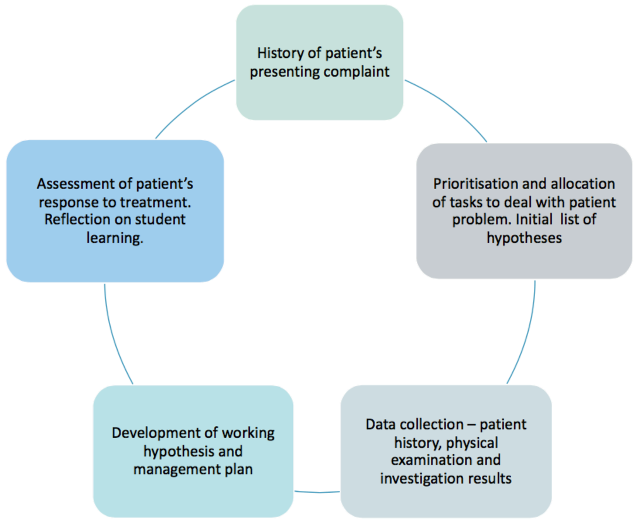

Figure 14. Five-stage cycle in simulation. Adapted from Kirkley et al. (2011).

The learning cycle in Figure 13 aligns closely with medical student simulation instructional design where the case is presented to the student team (the 'stem'); the leader then allocates roles based on identified priorities, and with the coach's assistance, the patient is stabilised, investigated and managed using clinical reasoning strategies. Hypotheses are developed and tested, management is initiated, outcomes are assessed, and students reflect on their learning. These points are illustrated in Figure 14.

Further, Oblinger (2004) offers an overview of game-based learning and argues that games serve six key learning functions:

1. They activate prior learning.
2. They teach 'players' the relationship between knowledge and context.
3. They provide 'rich feedback and assessment' of in-game actions.
4. They foster an environment that encourages the application of previously gained knowledge.
5. They accommodate experiential learners.
6. Being inherently social, they foster the sharing of knowledge. (p. 8)

These six functions align with several theoretical foundations of simulation-based learning and bring the key concepts of both simulation and gaming closer together. The activation of prior learning is a fundamental characteristic in simulation in that textbook knowledge of the associated condition is required in order for students to progress through the case. The purpose of simulation is not to teach that knowledge but to apply it in a clinical setting. Providing opportunities to explore the relationship between knowledge and context assists learners to reconceptualise textbook knowledge into clinical knowledge (Schmidt & Boshuisen, 1993). An in-game coach is able to provide 'in-the-moment' feedback on actions. Repeated opportunities for practice enable learners to apply knowledge learnt from previous simulations through the accumulation of instances. Learners construct and build on existing knowledge through team-based experiences in an authentic environment. Critical thinking and problem-solving contribute to improved team cognition through the sharing of knowledge.

1.8.2 In-game coaching

The role of teacher or facilitator within gaming opens up a wide range of possibilities influencing potential opportunities for adaptation to healthcare simulations. In particular, from an instructional design perspective, the role of coach provides a starting point for thinking about how to best support learning.

Alklind Taylor, Backlund & Niklasson, 2012) describe three teacher roles in serious gaming:

1. Facilitator, who provides structure and active guidance
2. Debriefer, who guides reflection on action and assesses performance
3. Coach, who is an in-game facilitator providing direction, information, scaffolding, and feedback in a non-obtrusive way that does not disrupt flow.

The roles of facilitator and debriefer are well described in the simulation literature, especially in relation to the two simulation styles mentioned in section 1.7.1 of this chapter. However, neither of these roles allows for the integration of just-in-time information, appropriate scaffolding, and feedback to support reflection in action without breaking the flow of the simulation, all of which align with the role of the coach in serious games. Schön (1983) describes an 'action-present' (p. 62) whereby immediate actions result from reflection that takes place in the midst of action without interrupting it. This concept has many appealing qualities for novice learners, in particular fast action feedback or instruction that can immediately be considered by the learners and guide their subsequent actions. This resonates with Clapper's (2015) view that in order to shift learners' frames using simulation, waiting until after the event may mean missing opportunities to do so.

Viewing the role of the coach in this way resonates with the model of cognitive apprenticeship described by Collins et al. (1989) in which they highlight the role of the coach as 'the thread running through the entire experience' (p. 2). This ensures that the thinking, both of the coach and the students, becomes 'visible' by bringing it to the surface. The coaching role within the cognitive apprenticeship framework utilises six strategies to develop learners' cognitive skills: modelling, coaching, scaffolding, articulation, reflection, and exploration (Collins et al., 1989). In simulation, there is an opportunity for these tacit processes to be woven into the action *as it occurs*, with both coach and students contributing to the dialogue in a reciprocal fashion. Explaining and demonstrating expert strategies in action gives students opportunities to understand how these strategies combine with their textbook knowledge and also how to use a variety of resources in context.

Within gaming, Iuppa and Borst (2007) describe the role of an 'instructor-in-the-loop' role who has multiple small interactions with learners to keep them focused and prevent mistakes or stalling. In this way, learners' actions and knowledge can be changed, allowing for the merger, in action, of scientific and everyday concepts into true concepts (Vygotsky, 1978) – referred to earlier in Chapter 1 as the reconceptualisation of biomedical knowledge into clinical knowledge.

Aklind Taylor et al. (2012) go one step further to describe the coach as a game-player alongside the learners. This concept of 'playing coach' or 'in-game coach' increases the active participation of the coach in the simulation activity, not just in the feedback or debriefing activity, resulting in a significant difference in the role to that of traditional facilitation. There are many benefits to the coach sharing the workload with learners, who are not only new to medicine but also to the concept of simulation. Challenges for these novice learners in simulation include:

- difficulty in knowing how to evaluate the situation, what to prioritise, and how to interpret data
- difficulty in locating relevant equipment and data

- difficulty in choosing an appropriate solution to a problem and resorting to trial and error
- difficulty in evaluating and reflecting on situations due to a lack of clinical experience and lack of knowledge of clinical standards
- becoming fixated on one particular issue or strategy due to a lack of situation awareness
- becoming overwhelmed with the amount and differing sources of information
- being unsure about the limitations around scope of practice constraints for junior doctors.

All of these factors increase interelement activity and risk cognitively overloading learners by overwhelming working memory.

Rather than interpreting the role of coach in a narrowly sporting context of drills and mechanical repetition through direct instruction, and therefore restricting the attributes associated with that role, the metaphor of coach in this setting encompasses a more sophisticated model of instruction. In particular, this includes deconstructing and demonstrating expert thinking into its component parts and fosters in the learner the development of cognitive skills required for expertise.

The term coach is a far more accessible term that situates the instructor as a member of the team rather than the expert other and is being increasingly utilised within medical education as a legitimate and formalised role (Graddy & Wright, 2016). New ways of thinking about what a workplace teacher does as a 'coach' (Eraut, 1994) or a 'guide' (Beckett & Hagar, 2002; Billett, 2001) have emerged in this field. An exhaustive guide to the numerous roles that teachers in medical education undertake was reported by Harden and Crosby (2000). They identified 12 teaching terms, with 'coach' being defined as the most all-encompassing of all the roles and primarily needing to be more adaptive to the learner than any other role through a wide variety of unique means.

Two important features of coaching within medicine are described that are considered superior to that of medical teacher. First, coaches aim to establish a goal of excellence rather than just competence, and second, they motivate learners to consistently improve (Graddy & Wright, 2016; Lovell, 2018). Another key dimension of the coaching role is the provision of feedback to students, not always present in traditional clinical teaching.

Coaching also features heavily as a teaching method in the cognitive apprenticeship framework that includes the content, sequencing of learning activities, and the social features of a community of practice (Stalmeijer, 2015), all of which feature strongly in simulation pedagogy.

The role of in-game coach has a number of positive implications for addressing these challenges and for reducing the number of interruptions to the simulation flow caused by timeout. Additionally, other positive implications of playing coach include the following:

1. Development of professional language. Research has shown that in science education, as students make meaning of scientific concepts, their scientific language becomes more authentic and allows for more meaningful discussion (Mestad & Kolstø, 2014). So too in medicine – as students experience the clinical application of their biomedical knowledge and new concepts are formed, medicalised language is learnt that encompasses the new concept. Simulation gives students an opportunity to authentically use this language, but this often requires encouragement and coaching, as students will tend to resort to 'student language' until they develop the professional confidence to use authentic language. Phrases such as 'Let's chuck some air on the patient' (let's administer oxygen) can be corrected in the moment by the coach supporting the students' use of authentic language, something normally considered too trivial to debrief in conventional simulation facilitation. This resonates with Lave and Wenger's (1991) concept of legitimate peripheral participation situating learners within the 'actual practice of professional discourse particular to their community of practice and assisting in making the culture of practice theirs' (p. 95).
2. Addressing groupthink. Apart from tasks related to ensuring fair play by addressing issues of group dynamics during action, another important coaching role is to encourage learners to challenge, question, and present alternative views within the group in order to prevent groupthink before poor decision-making affects performance. Groupthink results when the desire for group cohesion overrides good decision-making and problem-solving (Janis, 1972). The coach can encourage a more distributed approach to cognition by scaffolding problem identification (Fiore & Schooler, 2004). This ensures input from all team

members through the sharing of team mental models and team schema situation awareness, and by encouraging a dialogic approach to team decision-making.

Traditional simulation facilitation such as pause-and-discuss debriefs students during the simulation after a timeout is called when they have reached an impasse. However, refining that style of facilitation to that of in-game coach possibly leads to a more high-quality simulation experience with learning set within the framework of expert guidance (Schaffer, 2016). Rather than relying on discovery learning during the simulation action, learners are supported through explicit guidance by the coach to learn knowledge, skills, attributes and ways of expert thinking (Shaffer & Gee, 2005). Well-designed simulations can control appropriate aspects of the case so that limited working memory is used in the most efficient way.

Managing appropriate levels and types of cognitive load, maintaining a steady state of flow, encouraging critical thinking to improve team cognition, allowing for on-the-spot experimentation, and promoting socialisation into the profession through acting and role-play all contribute to optimal learning conditions. Brown, Collins, and Druid (1989), discussing situated cognition, claim that 'learning and acting are interestingly indistinct, learning being a continuous, life-long process resulting from acting in situations' (p. 33). Role-playing a junior doctor in simulations can be viewed as students learning while acting.

1.9 Simulation instructional design

The group of medical students engaged in the simulation described in the introduction to this thesis is participating in a simulation adapted to address issues related to the zone of proximal development, cognitive load, and the state of flow, not normally addressed together in simulation instructional design. According to Rupp, Gushta, Mislevy, and Shaffer (2010), 21st-century learners require exposure to well-designed complex tasks in simulated environments that afford them opportunities to interact with domain-specific experts who provide 'diagnostic feedback integrated into the learning environments' (p. 4).

The coach in the aforementioned simulation operates as a co-player giving feedback in a non-intrusive way and maintaining flow rather than interrupting 'gameplay' through pause-and-discuss. There are also cognitive aids used as scaffolds not usually present in the clinical environment, supporting learning by reducing extraneous cognitive load. These adaptations to conventional simulation design are not mentioned elsewhere in the healthcare literature but feature heavily in the serious gaming literature. Figure 15 was designed for the purposes of this study and represents three possible zones of learner activity within simulation. Ideal conditions are present in the green zone.

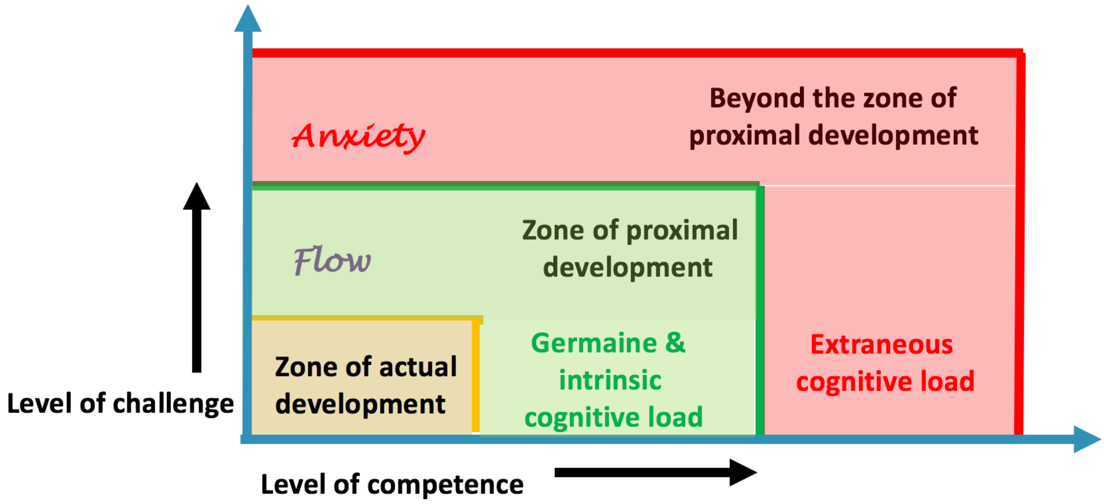

Figure 15. Zones of learner development.

For the aforementioned group of students, their reality is as a *learner* in a learning environment, not as a *clinician* in a clinical environment. They are not yet ready to *practice* medicine in a life-like environment, but instead require opportunities to *learn* medicine. They are undertaking a team-based, role-playing *learning* activity designed to allow them to draw on their propositional or textbook knowledge and apply it to a clinical situation. The frames, or mindset, students bring to the simulation are not the mature clinical frames of an experienced practitioner. Their frames are based on textbook knowledge taught to them at university and yet to be reconceptualised into clinical knowledge. The research suggests that medical schools applying a discipline-based curriculum find that learners cannot easily activate bioscience knowledge in a clinical situation (Laksov, Lonka, & Josephson, 2008). The purpose of simulation therefore is not to teach students about a particular condition – they already have that knowledge – but to coach them through a management process (or game) from start to finish in order to apply that knowledge in a practical way 'at the bedside' in order to achieve the desired outcome for the patient. There is very little evidence in the literature of using simulation in this way; that is, to reconceptualise biomedical knowledge into clinical knowledge, which is often described as the first step in the development of diagnostic reasoning skills (Schmidt & Boshuisen, 1993). In one study, Gordon (2010) introduced team-based simulation for pre-clinical students and suggested that it could aid in the contextualisation of basic bioscience knowledge into thoughtful action, thus 'accelerating the development of medical expertise' (p. 737). Tacketta, Scott, and Quirk (2018) recommend that practicing clinical reasoning for common conditions in simulated environments could ensure greater awareness of particular case presentations and reduce the risk of diagnoses being missed when they are encountered in clinical practice. For our students, the simulator is the vehicle for, and not the object of, clinical decision-making. Additionally, they are practising working in and as a team in order to facilitate team-based learning and performance.

In their 2010 critical review of simulation-based medical education research, McGaghie et al. identified 12 simulation-based medical education features and best practices as follows:

> *(i) feedback; (ii) deliberate practice; (iii) curriculum integration; (iv) outcome measurement; (v) simulation fidelity; (vi) skill acquisition and maintenance; (vii) mastery learning; (viii) transfer to practice; (ix) team training; (x) high-stakes testing; (xi) instructor training, and (xii) educational and professional context. (p. 52).*

These expert recommendations from McGaghie et al. (2010) along with Gaba's (2006) earlier recommendations for team training in simulation underpin the longitudinal simulation program embedded into a medical student curriculum to support the acquisition of both teamwork and taskwork skills necessary for acute patient management, which forms the basis for this research.

Salas, Diaz Granados, Weaver and King (2008) point out that simulation provides opportunities to practise both task- and teamwork skills in a 'consequence-free' environment where feedback is 'constructive, focused on improvement, and non-judgmental' (p. 1002). Simulation exercises are most successful when they become part of the standard curriculum and not an extraordinary, additional component (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005; McGaghie et al., 2010).

1.9.1 Cognitive apprenticeship

From a practical perspective, another relevant and important concept mentioned briefly in section 1.6.1.2 of this chapter is cognitive apprenticeship. Collins et al. (1989) succinctly define it as 'learning-through-guided-experience on cognitive and metacognitive, rather than physical, skills and processes' (p. 456). Central to cognitive apprenticeship as a method of learning are the concepts of situatedness and legitimate peripheral participation, guided instruction, and membership of a community of practice (Kirschner et al., 2006b; Lave & Wenger, 1991). Cognitive apprenticeship encompasses all the key points of the zone of proximal development, cognitive load theory, and flow theory raised in this literature review regarding learning. Managing acute clinical deterioration requires ability to process information in a stressful and dynamic atmosphere that requires *situated cognition.* Situated cognition refers to the activities, context and culture that influence the problem-solving process (Brown et al.,1989). This process of cognitive apprenticeship where the coach scaffolds the learning of the novice is one way of enhancing situated cognition. The cognitive apprenticeship framework outlines factors for creating learning environments that assist learners to acquire expertise by describing specific domain content, teaching methods, instructional sequencing, and the sociology of learning as represented in Table 6. The simulation curriculum is linked to each component of the dimensions.

Table 6. Cognitive apprenticeship dimensions (adapted from Brown et al., 1989)

Dimension	**Components of the dimension** – components of the simulation curriculum
Content	Domain knowledge – declarative and procedural Heuristic strategies – 'rules of thumb' Control strategies – coordination of taskwork Learning strategies – reconceptualising knowledge
Teaching methods	Modelling – thinking and behaviour Monitoring – prompting, suggesting, giving feedback Scaffolding and fading – applying support as required Articulation – learners thinking aloud Reflection – on performance Exploration – further learning
Sequencing activities	Global skills before local skills – task deconstruction Increasing complexity – of simulations over time Increasing diversity – of simulations over time

Sociology – the environment	Situated learning – within a relevant environment Culture of expert practice – community of practice Intrinsic motivation – learner driven Exploiting cooperation – teamwork

The literature pertaining to the use of cognitive apprenticeship in medical education describes it as a teaching method only, rather than a combination of the four dimensions in Table 6 that address the learning environments as well as the teaching that occurs within them (Daniel et al., 2015; Stalmeijer, Dolmans, Wolfhagen & Scherpbier, 2009). Although the concept of cognitive apprenticeship is based on Lave and Wenger's (1991) work observing traditional apprenticeship practices, it is far more focused on higher-order metacognitive skills and problem solving/task completion strategies employed by experts (Collins et al., 1989). First described in the 1980s in the context of secondary education in the United States by Collins et al. (1989), the cognitive apprenticeship framework has been introduced into the medical education landscape over the past 10 or so years. Despite the term 'apprenticeship' implying a lengthy training period, most of the literature pertaining to the use of cognitive apprenticeship in medical education refers to short-term projects (Stalmeijer et al., 2009). The teaching of clinical practice in medicine has long been described as an apprenticeship (Rangachari, Brown, Kern, & Melia, 2016), with learning opportunities arising as they come up in the workplace. However, this needs to be balanced with the every-day demands of the workplace where patient care takes priority over learning opportunities and supervision.

The simulated learning environment offers a compromise in this sense as it can foster situated learning that replicates substantial aspects of real-world clinical practice in an interactive manner that embeds the learning in a social and functional context (Collins et al., 1989). In cognitive apprenticeship, learning opportunities are sequenced to meet the needs of the learner and not the demands of the workplace. As in traditional apprenticeship, learning in cognitive apprenticeship occurs through legitimate peripheral participation, a view of learning in which newcomers enter on the periphery and gradually move toward full participation as a member in a community of practice (Lave & Wenger, 1991). However, as previously stated, the concept of medical students in clinical practice could be considered one of marginal rather than peripheral participation. Simulated activities offer opportunities to fill the void between the two and shift students closer to eventual full participation in a simulation community of practice.

In conclusion, Collins et al. (1989) adopted the zone of proximal development in developing their cognitive apprenticeship framework. In the context of this study, the zone of proximal development refers to the difference between what the medical students can achieve on their own in the setting of patient management and what they can learn under the guidance of an in-game coach. This forms the basis of the coaching intervention described in the next chapter.

1.10 Summary

This chapter has set the scene for the research. First, it describes the cognitive skills required by junior doctors entering clinical practice from the perspectives of both routine and non-routine acute patient management. Following on from there, a description of how those skills are taught and learnt along with how expertise develops revealed a need for training and further practice opportunities above and beyond those currently afforded to medical students. Simulation-based learning was discussed from a starting point of learning theory and progressed through to application of relevant theories in simulation instructional design with input from the world of serious games. In particular, a new facilitation role of in-game coach was developed in an attempt to support medical student learning in simulation

The next chapter describes the methodological approaches to the study with a focus on educational design research that aims to address educational problems in real-world settings. Its primary goals of developing knowledge and developing solutions make it a natural choice for this study.

Chapter 2: Methodology

2.1 Introduction

This chapter first sets out the rationale for the broad methodological approach to the study and the research design. This is followed by each of the processes used to answer the research questions, in particular data collection and analysis. Additionally, issues such as recruitment, validity and reliability, the intervention design process, and the role of the researcher are addressed.

Chapter 1 highlighted the importance of junior doctors having the skills, knowledge, and confidence to manage clinical deterioration from two perspectives: initial recognition and stabilisation, followed by clinical reasoning to find the cause. Additionally, the literature suggests that managing such a patient is a junior doctor's greatest fear as they feel ill-equipped to deal with such situations. Chapter 1 also made a case for adapting contemporary instructional design of simulations to better meet the specific learning needs of medical students. These two issues form the basis for the introduction of two interventions to the simulation program that underpin this research:

Intervention 1: The introduction of a component of clinical deterioration into all core presentation simulations in order to repeatedly utilise a structured approach to acute patient management.

Intervention 2: Replacement of the facilitator model of instruction in simulation with an in-game coach in association and other cognitive supports to improve the conditions for learning in simulation.

The purpose of this study is to generate a better understanding of the impact the two interventions have on a longitudinal, integrated simulation program and thus answer the following research questions:

> To what extent does a longitudinally embedded patient management simulation program develop medical students' ability to systematically approach patient management, and what evidence is there of retention and transfer of these skills?

- What taskwork skills are students required to develop in order to manage acute patient management?
- How does teamwork impact on the students' capacity to complete those skills?
- How might instructional design in simulation be developed to support the processes required to develop those skills?
- How can a new role of in-game coach enhance learning in simulation?
- How can optimal conditions for learning in simulation be operationalised?

2.2 The rationale for a qualitative approach

The focus of this study is on the development of the clinical knowledge and skills necessary for effective acute patient management. A qualitative constructivist approach has been utilised to observe the process of learner development and to form an understanding of not only how such development evolved but also what cognitive support structures were required to enable it. Additionally, a qualitative approach views learner development through the eyes of the learner. Epistemologically, researchers within the constructivist paradigm apply the role of co-constructor and engage with the participants to create understanding (Hesse-Biber, 2007). Capturing the participants' perspectives gives authentic meaning to real-life events by the people who live them, which may differ from the meanings held by the researcher (Yin, 2011).

Lofland (1971) posits four people-oriented mandates in collecting qualitative data:

1. *The researcher must get close enough to the people and the situation being studied to personally understand in depth the details of what goes on.*
2. *The researcher must aim at capturing what actually takes place and what people actually say: the perceived facts.*
3. *Qualitative data must include a great deal of pure description of people, activities, interactions and settings.*
4. *Qualitative data must include direct quotations from people, both what they speak and what they write down. (p. 4)*

As a participant observer in this study, I collected the data through direct observation, both *in action*, by being present in the simulations as the coach and at the focus group interviews as the interviewer, and *on action*, via observation of video-recorded simulations and focus group interviews and the creation of field notes. According to Patton (2015), a particularly strong type of qualitative inquiry combines fieldwork observations with in-depth interviewing. Although separated by time and technique, the integration of both data sources in this study generated meaningful and useful findings from the perspective of both the researcher and the participants.

2.2.1 Methodological choices

Methodological choices are often determined on practical levels such as the researcher's previous knowledge and experience as well as the collected data and thus regulate the way in which a research project develops (Patton, 2015). In seeking answers to the research questions in this study, two methodological choices were apparent that at first may appear incompatible. First, the medical student simulation program has a focus on constructive instructional design principles, best illustrated through a cognitive apprenticeship paradigm and is consonant with the contextualised process of constructing meaning and knowledge from activities and experiences. This is especially so for clinical reasoning, which is based on the construction of meaning from integrating patient signs and symptoms with other findings. It therefore follows that in this study constructivist inquiry would allow me to discover and construct what learning occurs in the real-world setting of the simulation laboratory, and to make sense of what the participants' actions and development meant to them via the focus group interviews.

Conversely, clinical deterioration focuses on a schema-based approach to patient management, where eventual automation of a patient management framework is preferred, lending itself to a more pragmatic methodological approach. An important difference between pragmatists and constructivists is that the latter typically conceptualise learning as construction of cognitive structures, whereas a pragmatist views it as seeking practical answers to concrete problems (Patton, 2015). Both of these approaches are required to answer the research questions.

Returning now to matters of methodological incompatibility, I am taking the view that classic pragmatism is not a methodology per se, but 'a doctrine of meaning or a theory of truth' as espoused by Denzin and Lincoln (2013, p. 51). Its focus is on developing an understanding of events taking place in a social situation. Denzin and Lincoln (2013) go on to say that the researcher examines, inspects, and reflects upon action and its consequences – a pragmatic take on constructivism. By adopting a stance of pragmatism being a view rather than a methodology, a qualitative approach, rather than the more pragmatically focused mixed-methods approach, is appropriate for this study.

2.2.2 Methodology

Educational design research is a 'design-meets-research' genre of inquiry combining the creative, dynamic features of design with the systematic, prescriptive and rigorous aspects of research (McKenney & Reeves, 2012). Educational design research is conducted in order to design and test interventions that solve educational problems through the development of creative approaches to learning and teaching while also constructing a set of design principles to guide future refinement (Gravemeijer & Cobb, 2006). Merrill (2007, p. 63) derived a set of principles to explain why instructional design processes (including educational design research) should be undertaken:

- Learning is promoted when learners are engaged in solving real-world problems.
- Learning is promoted when existing knowledge is activated as a foundation for new knowledge.
- Learning is promoted when new knowledge is demonstrated to the learner.
- Learning is promoted when new knowledge is applied by the learner.
- Learning is promoted when new knowledge is integrated into the learner's world.

These principles align closely with learning occurring in medical student simulation. Real-world problems of challenging acute patient management situations are presented to inexperienced students who require extensive biomedical knowledge in order to approach clinical problem-solving. The goal of the session is not to teach biomedical knowledge but to provide a meaningful framework for students to better understand and contextualise core propositional knowledge (Gordon et al., 2010). The application of biomedical knowledge to realistic patient presentations assists in reconceptualising that knowledge into new clinical knowledge. With the support of an in-game coach, that new learning can be applied in real time to an authentic patient problem. Learning in simulation also helps learners make sense of real-world experiences when they re-enter the clinical environment and observe clinicians in that setting.

In educational design research, practical learning interventions are designed, implemented, evaluated, and refined in order to address identified learning needs McKenney & Reeves, 2010). The aim is to produce innovative educational outcomes and new knowledge within learning environments (Kelly, Baek, Lesh, & Banna-

Ritland, 2008). Research that aims to 'test' designs, must do so in the context for which they are destined (Steketee & Bate 2013). The Design-Based Research Collective (2003) describes educational design research as 'a blending of empirical educational research with the theory-driven design of learning environments' (p. 5), which is congruent with many aspects of this study – research into forms of learning observed during a simulation program that is delivered in an innovative learning environment supported by cognitive load theory, flow theory, and triple loop learning theory. Educational research design in general, and this study in particular, does not aim to test theories but aims to design interventions based on theories and to assess the effectiveness of these interventions in practice (Walker, 2006). This research is based on the development of two instructional design interventions:

- A longitudinal simulation program offering opportunities for repeated practice of patient management frameworks designed to automatise clinical actions
- Cognitive support structures designed to enhance learning conditions – visual aids and in-game coach.

McKenney and Reeves (2012) describe the following characteristics of educational design research:

- ***Interventionist:*** *the research aims at designing an intervention in the real world*
- ***Iterative:*** *the research incorporates a cyclic approach of design, evaluation, and revision*
- ***Process orientated:*** *with the focus is on understanding and improving interventions*
- ***Utility oriented:*** *the merit of the design is measured, in part, by its practicality for users in real contexts*
- ***Theory oriented:*** *the design is based upon theoretical propositions, and field testing of the design contributes to theory building. (pp. 13–16)*

Application of those characteristics to this research design is illustrated in Table 7.

Table 7. Educational design research characteristics of this study

Interventionist	Two interventions have been designed for implementation into a pre-existing simulation program
Iterative	This research will incorporate the design and evaluation components of the cycle with suggestions for revision being included in the conclusions chapter
Process orientated	Interventions will be adapted and improved in action as required by the learners in addition to the evaluation component of the study
Utility orientated	Local instruction guidelines as an output of the study will support the utility of the interventions
Theory orientated	Relevant theory underpins the intervention design as well as the resultant local instruction guidelines

Ideal outcomes of educational design research include new alternatives for educational practice, new insights on the process of learning, and to contribute disciplinary knowledge (McKenney & Reeves, 2012) – all of which match the aims of this study. An alternative facilitation role of in-game coach coupled with inclusion of clinical deterioration into the simulation curriculum provides new alternatives for educational practice. New insights on skill acquisition will be described through the data analysis of students' learning progression over an extended simulation program. Local instruction guidelines developed as an output of the research will contribute to new disciplinary knowledge in simulation. Educational design research provides the rationale to understand and explain the meaning of learning from a constructivist perspective and to describe and test the means by which learning is cognitively supported from a pragmatic perspective, in turn producing new knowledge that influences simulation practice. An iterative cycle of design evaluation and revision continues as interim, experimental and modified outputs are refined (Cobb et al., 2001, p. 456).

Although many educational design research models exist, McKenney and Reeves (2012, pp. 78–80) describe the following approach, which forms the basis for this study:

1. Analysis and exploration
2. Design and construction
3. Evaluation and reflection.

Table 8 sets out the overall design process of this study based on the aforementioned approach and includes features and processes of this study along with anticipated outcomes.

Table 8. Overall design process of this study (adapted from McKenney & Reeves, 2012)

<table>
<tr><th>EDR features</th><th>Identification of issues</th><th>Processes</th><th>Anticipated outcomes</th></tr>
<tr><td>Analysis & exploration</td><td>Junior doctors' fear of managing a deteriorating patient
Lack of teaching a structured approach to deteriorating patient in the medical curriculum

Ad hoc nature of simulation-based education

Inappropriate instructional design of simulations for medical students</td><td>Identify the problems
1. Deteriorating patient
• Junior doctors fear managing a deteriorating patient
• Management of the deteriorating patient not a focus of medical education curricula
• Teamwork introduced late in the curriculum (if at all)

2. Simulation-based education
• Often ad-hoc and diagnosis-based
• Inadequate number of simulation experiences for medical students
• Inappropriate instructional design features of medical student simulations

Literature review
• Assess the problems
• Explore comparable contexts
▪ Serious games
• Explore alternative practices
▪ Serious games
• Identify design frameworks to support interventions
▪ Cognitive load theory
▪ Flow theory
▪ Triple-loop learning theory
▪ Cognitive apprenticeship</td><td>Define endpoints
• Evidence of medical students' ability to manage a deteriorating patient using a systematic approach
• Introduction in to the curriculum
• Evidence of effective teamwork, leadership, and communication strategies

• Development of a longitudinal, embedded simulation program offering opportunities for repeated practice
• Development of local instruction theory
• Examination of the learning trajectory in simulation and design of learning frameworks to measure learning development

• Clear definition of the problems
• Identification of commonalities and useful practice measures from other domains such as gaming
• Theory-driven instructional design concepts</td></tr>
</table>

		• Identify appropriate methodology	• Develop methodological stance for the research
Design & construction	Embed a longitudinal simulation program into the curriculum	Identify curriculum components and student clinical placement rotations to match simulations to appropriate learning	Students' learning is relevant and contextualised
	Focus learning on deteriorating patient stabilisation and management	Repeatedly foreground every core presentation simulation with a deterioration factor	Transition from novice to more expert performance in patient management
	Provide cognitive aids guide and support decision-making	Develop, trial, and refine cognitive aid prototypes sequenced in complexity to match learner experience and fade as appropriate	Evidence of use of cognitive aids with appropriate student-led withdrawal of supports
	Provide appropriate facilitation through a cognitive apprenticeship model	Develop and trial theory-based facilitation styles appropriate for the level of the learner. Determine the effectiveness of facilitation styles	Describe coaching characteristics Maintenance of scenario 'flow' No evidence of cognitive overload (absence of student stress) Decrease in coaching instances over time
	Apply relevant learning theory to instructional design	Identify and test theories that support cognitive apprenticeship	Theory-driven and justifiable design decisions
	Design a research project to measure impact	Use educational design research methodology to develop the project	Evidence of worthwhile research outputs such as learning frameworks, theory development, design principles
Evaluate & reflect	Collect multiple datasets	Collect data – video recordings and focus group interviews	All data collected and safely stored
	Observe, transcribe, and code data	Video recordings coded using Studiocode® event-marking software Focus group interviews transcribed verbatim	All coding completed • First pass • Second pass • Third pass
	Analyse data	Inductive thematic analysis	Analysis completed identifying emergent patterns, themes, and

			understandings
	Develop local instruction guidelines	Identify relevant components of each learning framework Develop local instruction guidelines	Learning frameworks developed • Taskwork – Loop 1 • Taskwork – Loop 2 • Teamwork Local instructional guidelines developed
	Analyse coaching episodes	Code and describe coaching episodes	Determine specific effective coaching episodes Identify the characteristics of the coach Develop domain-specific instruction theory
	Reflect on improvements to the simulation program	Ongoing critique of interventions • Curriculum modifications • Facilitation style • Cognitive aids	Ongoing reflection and refinement Develop design principles for simulation Recommendations for the next cycle – analysis and exploration of results followed by design and construction of the next iteration Recommendations for the future

Note. EDR = educational design research.

It is important to reiterate the cyclic or iterative nature of the overall design process. Kelly (2004) states that a design output must go through cycles of modelling and testing based on the empirical evidence of how each iteration of the design performs when in real-world use.

Within the overall design, three cycles are identified: micro-, meso-, and macro-cycles. Each time one of the main phases is undertaken, one micro-cycle occurs. Figure 16 (McKenney & Reeves, 2012, p. 78) illustrates a sample design research process with three micro-cycles making up one meso-cycle and two meso-cycles making up one macro-cycle. However, in reality, most educational research design macro-cycles involve numerous meso-cycles over long periods of time (McKenney & Reeves, 2012).

That said, McKenney and Reeves (2012) also explain that as educational design research is a genre of enquiry, rather than a fixed method, there are a variety of different approaches to conducting research. Added underneath Figure 16 in colour are the sections of this research linked to corresponding educational design research phases. In this case, the research questions were developed to analyse and explore interventions that were previously designed and trialled informally prior to the conceptualisation of this study. In other words, the research questions evolved *from* the initial implementation of the interventions rather than as the *basis for* their introduction. Subsequently, the first iteration of the interventions had already been implemented, but not fine-tuned, prior to the commencement of this study. Study findings will inform and shape the next iteration of the two interventions previously described in this chapter.

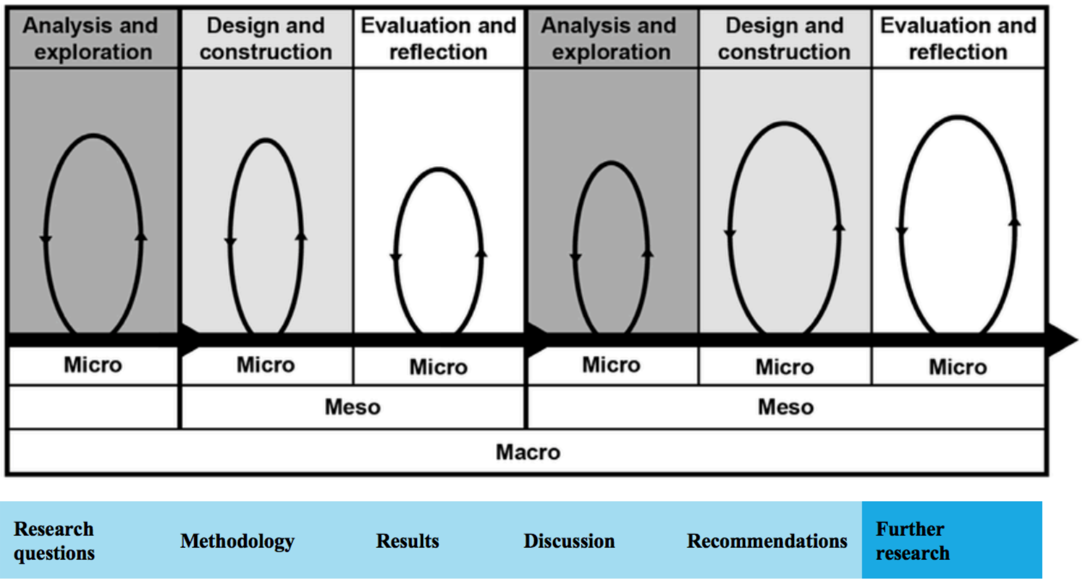

Figure 16. Educational design research process (Adapted from McKenney & Reeves, 2012. P 78)

In Figure 16, this research is demonstrated in the context of the micro-, meso-, and macro-cycles of educational design research adapted from McKenney and Reeves (2012, p. 78). Another way of conceptualising this study in relation to one complete macro-cycle is shown in Figure 17.

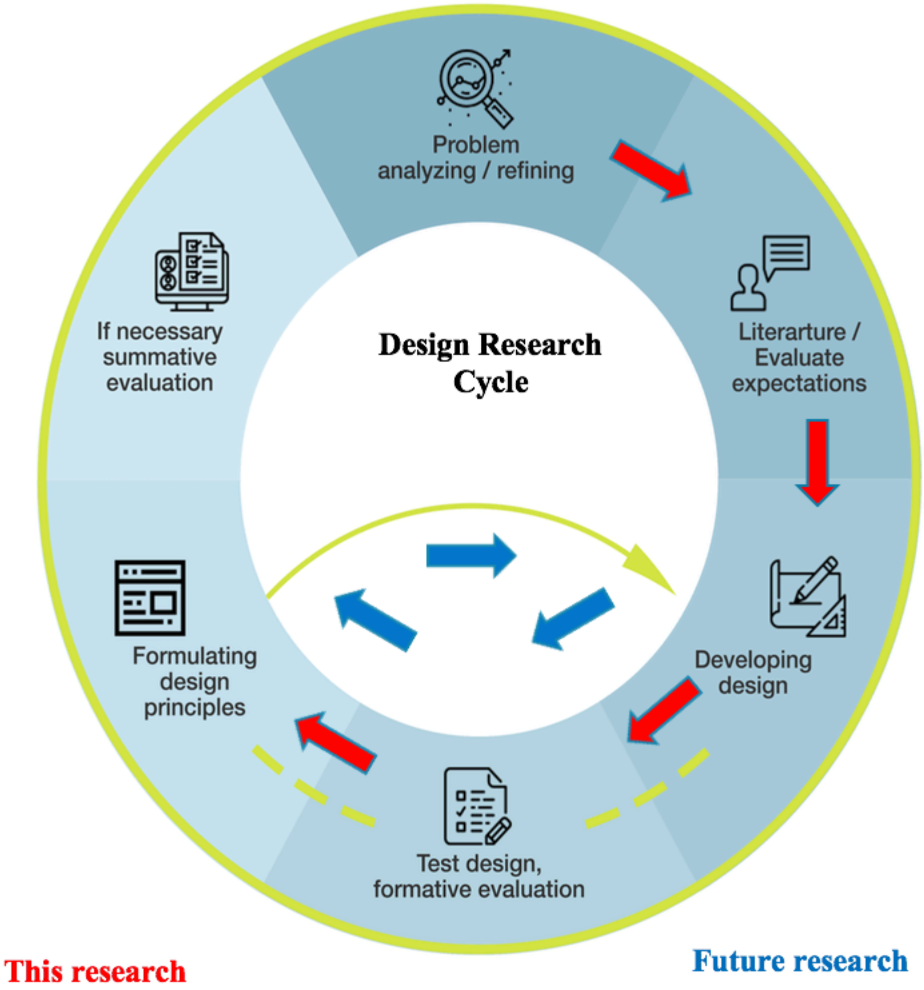

Figure 17. The design research cycle. (Adapted from Seamless Learning).

Red and blue arrows have been applied to this cycle to indicate the particular components of this study. Future research will continue the iterative process of further refinement to the interventions.

Two basic educational design research orientations to the study have been applied. The two basic orientations are research conducted *through* the intervention and research conducted *on* the intervention (McKenney & Reeves, 2012). First, in order to address the primary research question of learning, researching the intervention of a longitudinal, embedded simulation program underpinned by repeated practice of a structured patient approach is orientated to research conducted *through* that intervention. This means that the intervention serves as the research context providing a means by which the specific phenomena related to that context are studied. In other words, it focuses on understanding the responses the intervention elicits. In contrast, to address the question of what cognitive support is required to achieve learning, the research focuses explicitly *on* characteristics of the intervention, such as simulation facilitation style and cognitive supports, and how that intervention works and under what conditions. This orientation focuses on qualities of the intervention as an end to meet certain goals (McKenney & Reeves, 2012). A conceptual framework forming the basis of the research and its theoretical underpinnings is represented in Figure 18.

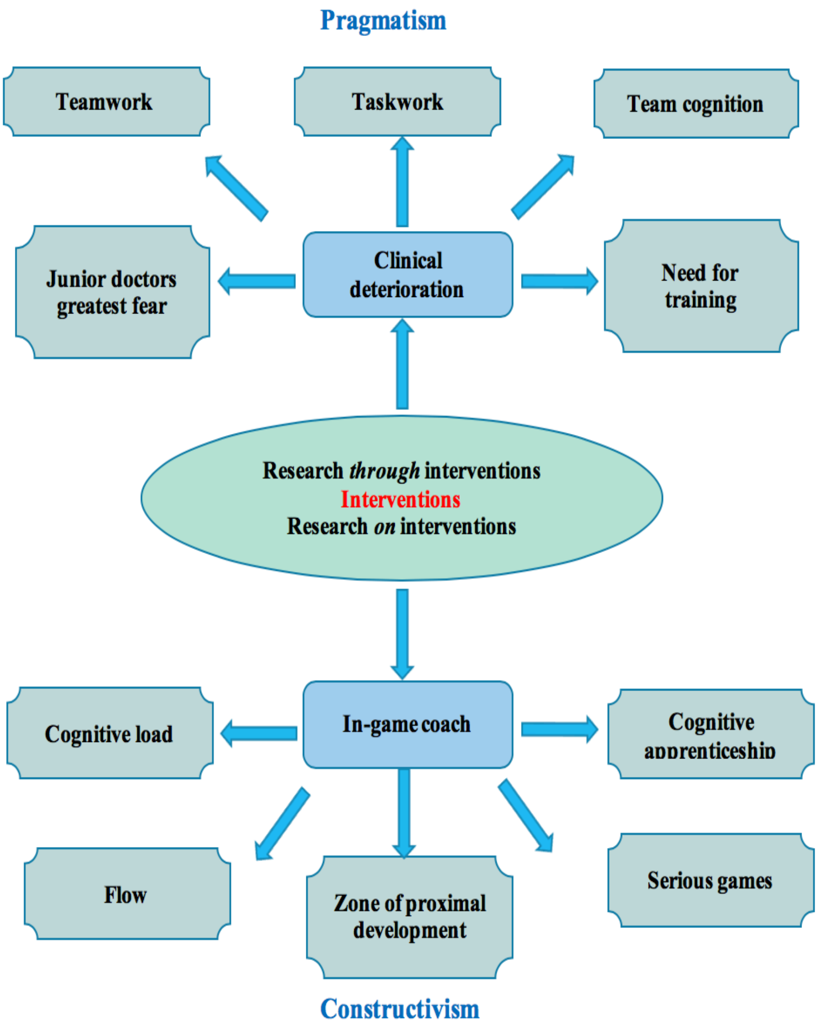

Figure 18. Conceptual framework for the study.

2.2.2.1 Interventions

Intervention 1: Inclusion of clinical deterioration into core presentation simulations

Prior to this research, the simulation program for second-year medical students included case-based presentation of 'core' medical and surgical conditions such as heart attack, asthma, and surgical problems in which students applied clinical reasoning skills to solve the clinical problem. At that time, clinical deterioration was introduced late in fourth year in two 'real-time' simulated cases that focused only on clinical deterioration and were not embedded or 'situated' within a broader case. Based on issues of junior doctors feeling inadequately trained to manage clinical deterioration, a decision was made to introduce clinical deterioration into all second-year core simulations to provide opportunities to repeatedly practise a structured approach to such an event. This earlier introduction of the taskwork and teamwork skills required for patient stabilisation into the medical curriculum meant more opportunities to practice such skills during simulations that were not time-pressured or critical. Additionally, the clinical deterioration component of each simulated case embedded that aspect of management into a broader case, which also required clinical reasoning skills, thus making it a more realistic and holistic experience. The supported and non-time-pressured nature of the second-year simulation environment reduced the stressful aspect of clinical deterioration, and, as a result, skills could be overlearned at a distributed pace. As discussed in Chapter 1, triple-loop learning provided a practical framework on which to design simulations that broke down the components of patient management into Loop 1 (clinical deterioration) and Loop 2 (clinical reasoning skills). For the purposes of this study, Loop 3 learning was addressed as student reflections on learning in focus group interviews.

Intervention 2: In-game coach

Chapter 1 highlighted the issues surrounding simulation facilitation styles and their lack of applicability to second-year-level learners. In particular, the extraneous cognitive load placed on learners in a high-fidelity, time-pressured, and multi-factorial environment was considered detrimental to learning. The cognitive apprenticeship model was identified as a suitable application on which to base an in-game coaching model. As briefly mentioned in section 1.9.1 in Chapter 1, a key dimension of Collins et al.'s (1989) cognitive apprenticeship instructional model is the six teaching methods, falling into three groups, utilised to support learning: modelling, monitoring, and scaffolding, which assist learners to acquire an integrated set of skills through processes of observation and guided practice; articulation and reflection, which assist learners to develop their own problem-solving strategies; and exploration, which is aimed at encouraging learner autonomy when developing such strategies.

1. *Modelling* involves actively demonstrating and explaining skills through externalising mental processes.
2. *Monitoring* refers to observing students and providing specific and corrective feedback on performance by offering hints, feedback, reminders, and prompts.
3. *Scaffolding* refers to the support the teacher provides to assist the learner in carrying out the task, such as suggestions, physical supports, and conceptual models. Fading involves the gradual removal of supports until students can manage on their own.
4. *Articulation* involves any method of getting students to articulate their knowledge, reasoning, or problem-solving processes by explaining their rationale.
5. *Reflection* involves enabling students to compare their own problem-solving processes with those of an expert and ultimately an internal cognitive model of expertise.
6. *Exploration* involves pushing students into a mode of problem-solving on their own. Exploration is the natural culmination of the fading of supports. (Adapted from Collins et al., 1989)

Most of these methods are clearly interlinked and cannot be easily separated: some forms of coaching can be depicted as scaffolding, modelling can be depicted as scaffolding, giving feedback can be considered as coaching, and so on, making a clear categorisation challenging. Nonetheless, these teaching strategies are designed to provide learners with opportunities to make sense of the complexities of expert thinking through the provision and fading of scaffolding in a functional and social context (Collins et al., 1989).

2.2.2.2 *The simulation curriculum*

Prior to the commencement of the formal simulation program, three introductory simulations were conducted to introduce students to the simulation system and the patient management frameworks they were to utilise in subsequent simulations. All of the steps required in acute patient management were initially decontextualised and broken down into manageable tasks. This was followed up with a worked example by the coach where the skills were contextualised into a simulated patient case. An action-cue poster complemented the instruction. This was an incrementally staged process over the three simulations, again based on Collins et al.'s (1989) cognitive apprenticeship model, supported by the poster and designed to provide students with

1. an advanced organiser for learners' initial attempts
2. an interpretative structure for making sense of future feedback, hints, prompts, and corrections from the coach
3. an internalised guide for when independent practice will eventually be attempted
4. a way for learners to reflect and continuously update their developing understanding.

Introductory simulations were broken down into the following skill sets:

- **Simulation 1:** Introduction to the simulation program: Familiarisation to the patient mannequin, the environment, and the simulation systems
- **Simulation 2:** DRSAB
- **Simulation 3:** CDEFG

The following table expands and contextualises Collins, Brown, and Holum's (1991) four-dimensional framework for designing cognitive apprenticeship learning environments by mapping the entire simulation program against it.

Table 9. Cognitive apprenticeship content domains (adapted from Collins et al., 1991)

Content	Relevance to the simulation program
Domain knowledge (Textbook knowledge)	First-year university learning – biomedical knowledge
Heuristic strategies	First-loop learning – 'fix-as-you-go'

(Rules of thumb)	patient stabilisation
Control strategies (Problem-solving)	Second-loop learning – clinical reasoning
Learning strategies (Reflecting on learning)	Third-loop learning
Teaching methods	**In-game coach**
Modelling	Demonstrating/explaining/thinking out loud
Monitoring	Feedback/prompts/reminders
Scaffolding	Suggestions/physical supports/conceptual models/mnemonics
Articulation	Thinking out loud/explaining rationale
Reflection	Comparing thinking to an expert/comparing thinking to own internal cognitive model
Exploration	Problem-solving and reasoning
Sequencing activities	
Global before local skills (Conceptual model first)	Introductory simulations
Increasing complexity (Task sequencing)	First simulations easier than subsequent simulations
Increasing diversity (Wider variety of strategies are required)	Provided through rotating terms and pop-up simulations
Sociology – the environment	
Situated learning (Environment reflects the multiple uses to which their knowledge will be later put)	Simulation lab reconfigured for each simulation to reflect the environment; e.g., medical ward/emergency department
Community of practice (Participants actively communicate and engage)	Small group learning – common tasks and shared experiences in a social environment
Intrinsic motivation (Learning linked to an intrinsic goal)	Summative assessment-free environment

Exploiting cooperation (Working together on problems)	Teaching teamwork/leadership/communication skills. Development of group cognition

2.3 Participant recruitment

Ethics was approved by the Melbourne Graduate School of Education's Human Ethics Advisory Group at The University of Melbourne. The Clinical Dean of the associated clinical school gave permission for student participation. The entire 2016 second-year medical student cohort was approached at the completion of an 8-week introductory term, which included three introductory simulations. It was considered important for the students to have experienced those initial simulations in order for them to fully understand the implications of their involvement in the research. A plain language statement (see Appendix B) and consent forms were distributed to all students (see Appendix C).

Completed consent forms were returned to the Manager of the clinical school and 62 out of a possible 63 students consented to participate. The researcher was blinded to the identity of the non-consenting student and was only informed of which group was eliminated from the study due to its non-consenting member. This ensured anonymity of any non-participating students and prevented any perceived pressure to agree to participate in the study from the researcher or other students. My role as simulation facilitator meant that I was obliged to undertake the role of coach and of researcher. This is common in educational design research where the researcher is often the developer, the facilitator, and the evaluator of the interventions (McKenney & Reeves, 2012). In order to remain neutral and teach without bias, all consenting groups (11 in total) were video-recorded over the course of the year without me knowing which groups would make up the eventual sample group. Three groups were subsequently selected by a colleague at the completion of the second-year simulation program.

2.3.1 Sample size

In discussion with my supervisors, it was decided that three groups would eventually make up the sample group for the study. In the absence of any appropriate literature to inform this decision, considered expert opinion suggested that this size sample would be adequate to achieve saturation. According to Patton (1990), 'there are no rules for sample size in qualitative research. The sample size depends on what you want to find out, why you want to find it out, how the findings will be used, what will be useful, and what resources are required' (p. 184). It was therefore decided that 27 simulations producing approximately 30 hours of video footage would generate adequate data (18 x second-year simulations, 3 x pop-up simulations, 6 x fourth-year simulations; see section 2.41 for details).

This purposive sample of three groups was selected at the completion of the simulation program by a simulation colleague. Any risk of perceived teaching bias towards the sample group during coaching in the simulation sessions was thus eliminated. The three groups were selected based on their performance in their first (of six) simulations: one group who performed well, one group who performed poorly, and one group somewhere in the middle. This allowed for data analysis of individual group learning over time and for comparison between groups at salient times during both the program and the research.

2.3.2 The participants

As stated, three groups of second-year medical students were the eventual participants in the study. The three groups each had five members with a mix of gender and cultural backgrounds and included local and international students. Students remained in predetermined groups for the duration of the four-year medical course. At the completion of second year, students left the clinical school (considered their home base) to undertake third-year rotations at various specialty locations. Subsequently, the first six months of fourth year were spent undertaking research projects, and the groups finally returned to the clinical school in July 2018. In those intervening 18 months, the students did not participate in any simulations, nor did they practise any acute adult medicine. For an overview of the entire MD curriculum, please see Appendix D

2.4 Methods

Data for this research project was generated over a period of 2.5 years. An overview of methods and their links to the data analysis informing the research questions is presented in Table 10. Three data collection tools were used: video-recorded simulations, field notes, and focus group interviews. The contributing research questions to the major research question are listed below. The key terms that relate to the data generated are italicised in the questions to demonstrate the strong alignment between the data and the questions.

- What *taskwork skills* are students required to develop in order to manage acute patient management?
- How does *teamwork* impact on the students' capacity to complete those *skills*?
- How might instructional design in simulation be developed to support the processes required to *develop those skills*?
- How can a new role of in-game coach *enhance learning* in simulation?
- How can *optimal conditions for learning* in simulation be operationalised?

Table 10. An overview of data collection and analysis with links to the research

Activity	Year level	Date	Data elements	Research relevance	Analysis
Simulations	2nd year	April–October 2016	18 x 90-minute video-recorded simulations 3 x 30-minute pop-up simulations	Learning: Taskwork Teamwork Coaching Cognitive aids Development of learning frameworks Transfer: Taskwork Teamwork	Inductive and deductive computer-assisted qualitative data analysis using Studiocode®
Field notes	2nd year	April–October 2016	54 pages of field notes	Learning: Taskwork Teamwork Coaching Cognitive aids	Descriptive and reflexive notes coded inductively by hand
Focus group interviews	2nd year	October 2016	3 x 45-minute audio-recorded interviews	Student reflections on learning: Taskwork Teamwork Coaching Cognitive aids	Inductive in-vivo coding by hand
Simulations	4th year	July 2018	6 x 30-minute video-recorded	Retention and transfer:	Deductive computer-

			simulations	Taskwork Teamwork	assisted qualitative data analysis using Studiocode®
Field notes	4th year	July 2018	5 pages of field notes	Retention and transfer: Taskwork Teamwork	Descriptive and reflexive notes process-coded inductively by hand

2.4.1 Simulations

Simulation activities took place at the clinical school's simulation and skills centre. The centre houses a fully computerised high-tech adult mannequin (Laerdal SimMan®) situated in a realistic clinical environment (see Figure 19). SimMan's capabilities include realistic breathing, the presence of pulses, heart sounds and lung sounds, reactive pupils, and the ability to speak. The mannequin's voice is of particular note – it adds an important element of emotional realism to the situation and enables the students to take a patient history, both of which contribute to learner engagement. All relevant clinical equipment such as a patient monitor and other technical devices is available for student use.

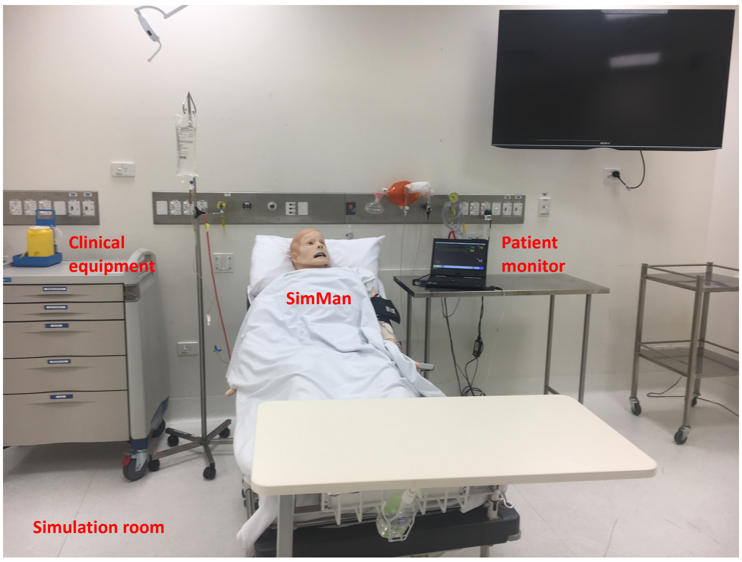

Figure 19. Simulation room.

On the other side of a one-way mirrored wall, a console operator in a control room provides technical and computer support to adjust vital signs such as heart rate and blood pressure (see Figure 20). The console operator also acts as the patient voice via a microphone in the control room and a speaker in the mannequin's head.

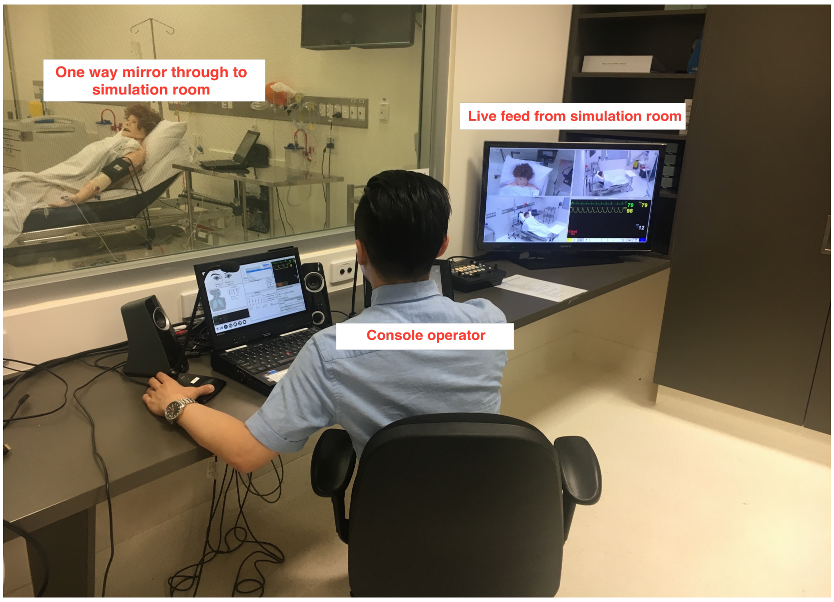

Figure 20. Console operator in control room looking through to the simulation room.

A quad-view-enabled recorded capture of all the simulation room activity from three different angles and included a simultaneous download of the patient's vital signs monitor (see Figure 21).

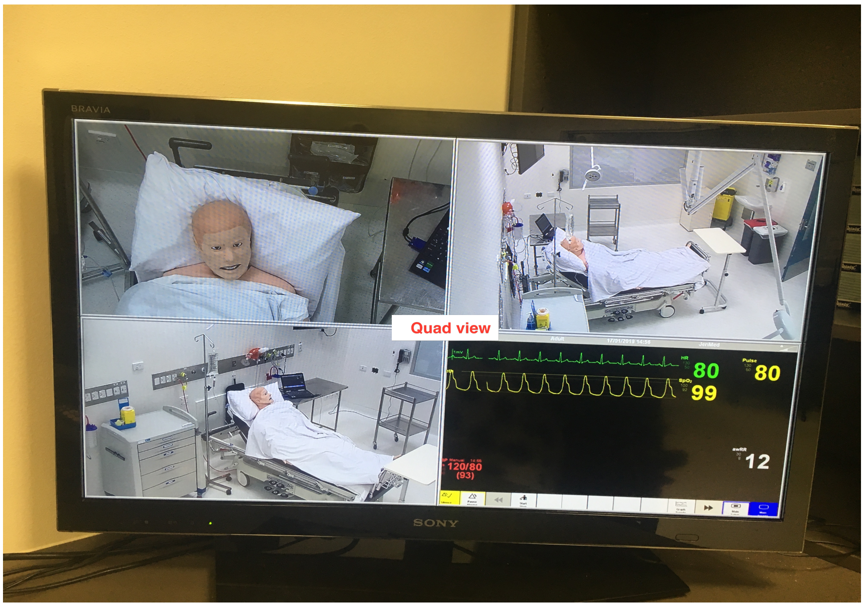

Figure 21. Quad-view ceiling cameras.

The console operator manipulates the patient's physiology on a laptop computer based both on the scenario script and in response to student actions (see Figure 22); for example, altering the blood oxygen concentration based on the dose of oxygen being administered to the patient. This response to treatment provides instantaneous clinical feedback to students.

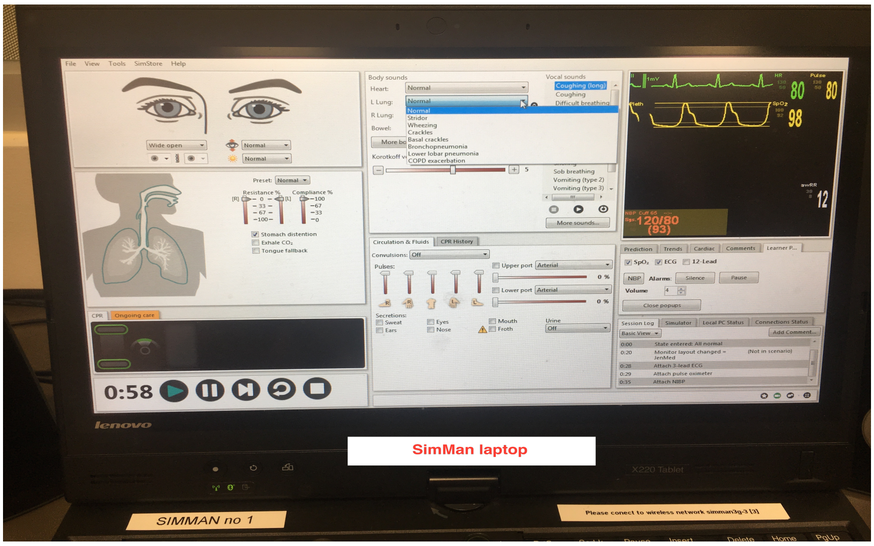

Figure 22. SimMan® laptop to control physiological parameters.

All participants in the study were attached to the clinical school and the simulations were part of their set curriculum. Simulations were recorded to increase the precision of the fieldwork and to stimulate the researcher's memories of the events (Yin, 2011). Recording of simulation activities was achieved through in-built audiovisual infrastructure located in the simulation centre. Three unobtrusive ceiling-mounted overhead cameras and a direct download of the patient monitor captured a quad-view perspective of activities, as seen in Figure 21. Of the three cameras, one captured a wide-angle view of the students around the bedside, one captured a narrower overhead view, and another captured a view of the whiteboard with cognitive aids on display. The camera angles remained consistent across all simulations.

After the introductory simulations, groups of students engaged in a further six 90-minute simulated cases over the course of the second year, which were part of the timetabled curriculum. Each simulation was linked to each particular group's clinical rotation, which is an attachment to specific clinical areas such as medical wards, surgical wards and operating theatres, outpatient clinics, and the emergency department. Simulations conducted during these rotations matched the clinical placement. For example, medical simulations are medical cases such as heart attack or abnormal heart rhythm, surgical simulations are surgical cases such as postoperative fever or postoperative bleeding, and emergency simulations are emergency cases such as allergic reactions or altered consciousness. As stated earlier, each of these cases was foregrounded with patient deterioration, which needed to be initially recognised and managed using a structured approach prior to the application of case-based clinical reasoning approaches.

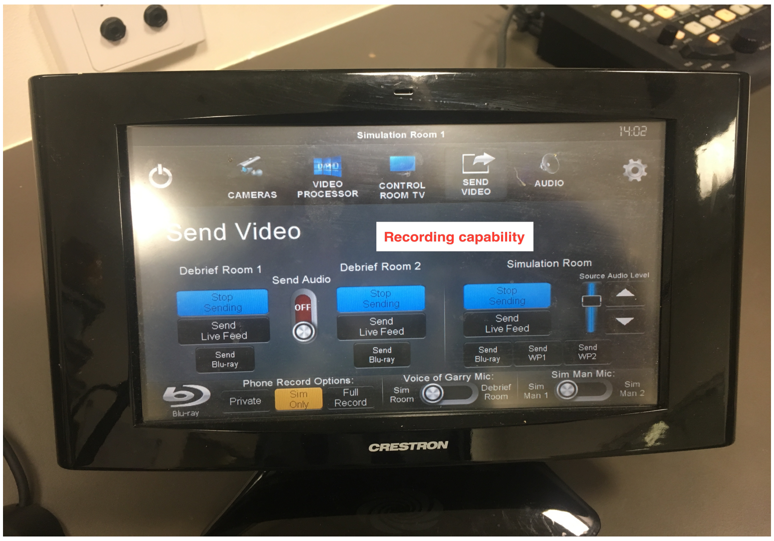

Figure 23. Recording capability monitor.

Six second-year simulations were recorded over an 8-month period from March to October 2016 for this study. Students did participate in other types of simulations, but these were excluded from this study as they were not case-based. Optional ‘pop-up’ simulations were conducted at the end of the second year to assess learning transfer (Table 12). These were unscheduled ‘spur-of-the-moment’ simulations designed for students to practise working in unfamiliar teams at unexpected times. Fourth-year simulations were also recorded to assess for retention and transfer of skills learnt in second year. In fourth year, each group participated in two simulations on the same day as mandated by the university (Table 13). All simulations in this study included an element of clinical deterioration, and the conditions being addressed by the students were severe and life threatening.

2.4.1.1 The simulated cases

Table 11. The second-year cases

Date	Group 1 topic	Date	Group 2 topic	Date	Group 3 topic
12/4/16	Heart attack (Myocardial infarction)	13/4/16	Heart attack	26/4/16	Altered consciousness
12/5/16	Severe urinary tract infection (Urosepsis)	13/5/16	Severe urinary tract infection	11/8/16	Postoperative infection
18/5/16	Abnormal heart rhythm (New onset atrial fibrillation)	5/7/16	Severe allergic reaction	18/8/16	Fluid on the lungs
7/7/16	Severe allergic reaction (Anaphylaxis)	4/8/16	Altered consciousness	22/9/16	Heart attack
14/9/16	Postoperative infection (Abdosepsis)	15/9/16	Postoperative infection	28/9/16	Abnormal heart rhythm
7/10/16	Fluid on the lungs (Acute pulmonary oedema)	6/10/16	Fluid on the lungs	13/10/16	Severe urinary tract infection

Table 12. The second-year pop-up simulations

Date	Pop-up 1	Date	Pop-up 2	Date	Pop-up 3
20/10/16	Drug overdose (Narcosis)	19/10/16	Pneumonia (Sepsis)	20/10/16	Pneumonia (Sepsis)

Table 13. The fourth-year simulations

Date	Group A topic	Date	Group B topic	Date	Group C topic
19/7/18	Postoperative bleeding	19/7/18	Vomiting blood	19/7/18	Postoperative bleeding

	(Thyroid)				
19/7/18	Vomiting blood (Haematemesis)	19/7/18	Postoperative bleeding	19/7/18	Vomiting blood

2.4.2 Field notes

Ideally, field notes would be recorded in real time or at the completion of each simulation; however, as coach/researcher, it was not possible. Such was the focus and intensity of the coaching role, I felt unable to perform the dual roles of coach and researcher during the simulation action. Instead, I completed a set of retrospective observational field notes as the first step of data familiarisation by watching each video-recorded simulation in real time, prior to the commencement of coding. The field notes were both descriptive and reflective (Creswell, 2014). During subsequent coding, the field notes were used to verify the analysis, thereby adding another data component to the triangulation process.

2.4.3 Focus groups

The study design included a series of 'convergence-focused' (Creswell, 2014, p. 475) group interviews over its duration to gain an authentic insight into participants' perceptions and understandings. Convergence based refers to the use of data collected in the second-year interviews to inform the discussion in the fourth-year interviews. The sample group of three groups of students, having had shared common experiences, were interviewed at the completion of the second-year simulation program and again at the completion of the fourth-year simulation program. Semi-structured interviews were conducted to gather additional information that could verify patterns and perceptions (Savenye & Robinson, 1997), help to interpret or explain a phenomenon (Kratz, 2010), and to allow for unexpected insights to be collected, clarified, and explored further (O'Toole & Beckett, 2013).

The second-year focus group interviews were also video-recorded at the clinical school simulation and skills centre in a deconstructed simulation room. A core component of the second-year focus groups was for each group to watch the recordings of both their first and their sixth simulations as a stimulus for discussion. Using the simulation facility allowed the researcher to simultaneously video record the interview and the video-recorded simulation activity the group was watching at the time of their comments on a split-screen configuration. The added paralinguistic dimension of interview video footage, as opposed to just audio, enabled a more nuanced interpretation of the interviews through the identification of cues and gestures to support or refute opinions or responses (e.g., head nodding). Fourth-year interviews did not include the students viewing their recorded simulations as the interviews were conducted immediately after the simulations concluded when student recall was readily activated. Fourth-year interviews were audio-recorded instead.

My aim was to get high-quality data within a social context where participants could examine their own views in the setting of others, as described by Creswell (2014). Using the visual medium of recorded simulations in conjunction with semi-structured prompts stimulated discussion based on identified themes linked to the research questions:

1. Second year
   Learning:
   - How did simulation contribute to learning?
   - How did performance differ between the first and last simulations?
   - How did simulations contribute to learning in the real world?
   - How did the coach support learning?
   - How did the cognitive aids affect learning?

2. Fourth year
   Retention and transfer:
   - How did the simulation exercise stimulate recall of prior learning?
   - How did students perceive their recall?
   - What were their overall impressions of the simulation program?

The second-year interviews intended to uncover how students perceived learning in simulation and why such learning occurred. It provided an opportunity for students to express their views on reconceptualising textbook knowledge as clinical or practical knowledge. Viewing their recorded simulations gave students the opportunity to visualise their learning progression and comment on it, and to also comment on the cognitive support they received during the simulations. The fourth-year interviews were designed to capture students' views on retention and transfer of knowledge and skills learnt in second year. It also enabled them to describe the ease or difficulty with which they were able to apply previous learning to a similar but higher acuity simulated case. The group interviews also provided flexibility to explore unanticipated themes as they arose in discussion.

2.5 Data collection, management, and analysis

2.5.1 Collection and management

All simulations were video-recorded via a direct feed from the simulation and skills centre's audiovisual infrastructure to the researcher's laptop computer. The recordings were labelled using protected codes according to a randomly allocated group number and simulation number. No names or other identifying data were included. All recordings were backed up with three Lacie® hard drives, each securely stored in three different locations. Similarly, focus group interviews were either video-recorded or audio-recorded, deidentified, and stored in the same manner. Interviews were subsequently transcribed verbatim by hand. Field notes were written by hand during the initial data familiarisation phase.

2.5.2 Analysis

Data analysis involved a process of disassembling the data through inductive, deductive, and in-vivo coding, as illustrated previously in Table 10. Thematic analysis of the simulations was one of analytic induction (Patton, 2015) in which the starting point was a deductive analysis of the data in terms of a theoretical framework or concept – in this case, Loop 1 and 2 frameworks – followed by inductive analysis looking for emergent patterns, themes, or understandings. Inductive coding was used in the analysis of focus group interviews and field notes.

2.5.2.1 Simulations

Simulated scenarios were coded using Studiocode® event-marking software in which the video-recorded MPEG file is populated by event codes and transcriptions of particular utterances. My approach to analysis and interpretation was consistent with the overall rationale for taking a qualitative approach to research. Observation of each second-year simulation recording in real time prior to coding individual events or instances was initially undertaken. This provided overall familiarity with the recordings and the basis for an inductive approach to future coding. Creswell (2014) describes this as a ‘preliminary exploratory analysis’ (p. 267) to obtain a general sense of the data. From there, initial coding of both participant action and coaching episodes was achieved using the SOLO (structure of observed learning outcomes) taxonomy (Biggs, 1995) as a framework to distinguish various learning development categories. As codes are intended to be prompts or triggers for deeper reflection on the data’s meaning (Miles, Huberman, & Saldana, 2014), it became apparent after completing the coding that the SOLO taxonomy was not specific enough in identifying the necessary behaviours required to develop Studiocode® timelines.

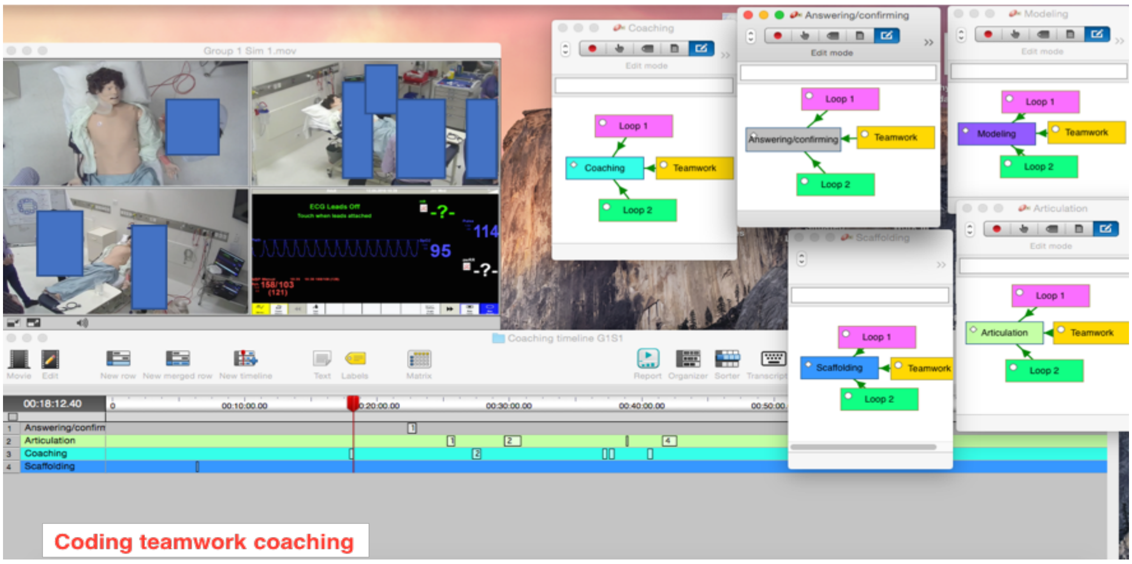

Figure 24. Screenshot of coaching coding using Studiocode®.

Returning again to the research questions helped to focus the coding more specifically on the categories required to cover all aspects of the two interventions I was evaluating: the curriculum content and the cognitive support, otherwise described as the learning and the coaching. From a learning perspective, a return to the curriculum intervention patient management learning frameworks now appeared to be the obvious action to code and they provided the basis for initial deductive coding. How closely were students adhering to those processes and how effectively and appropriately did they move between patient stabilisation and clinical reasoning? In other words, how and why did Loop 1 (clinical deterioration steps) and Loop 2 (clinical reasoning steps) start to merge as is seen when expertise develops? Further, what was it that enabled students to do so? The subsequent coding of Loop 1 and 2 action then became more **deductive** in nature as the components of the standardised approaches to patient management were developed into learning frameworks. Coding definitions were co-constructed between researcher and supervisor to ensure clarity and reliability. Some cross-case analysis was also undertaken to compare group activities, learning, and development. Subsequent inductive approaches were more appropriate for discovering enabling behaviours and ensured that other fresh insights were not overlooked.

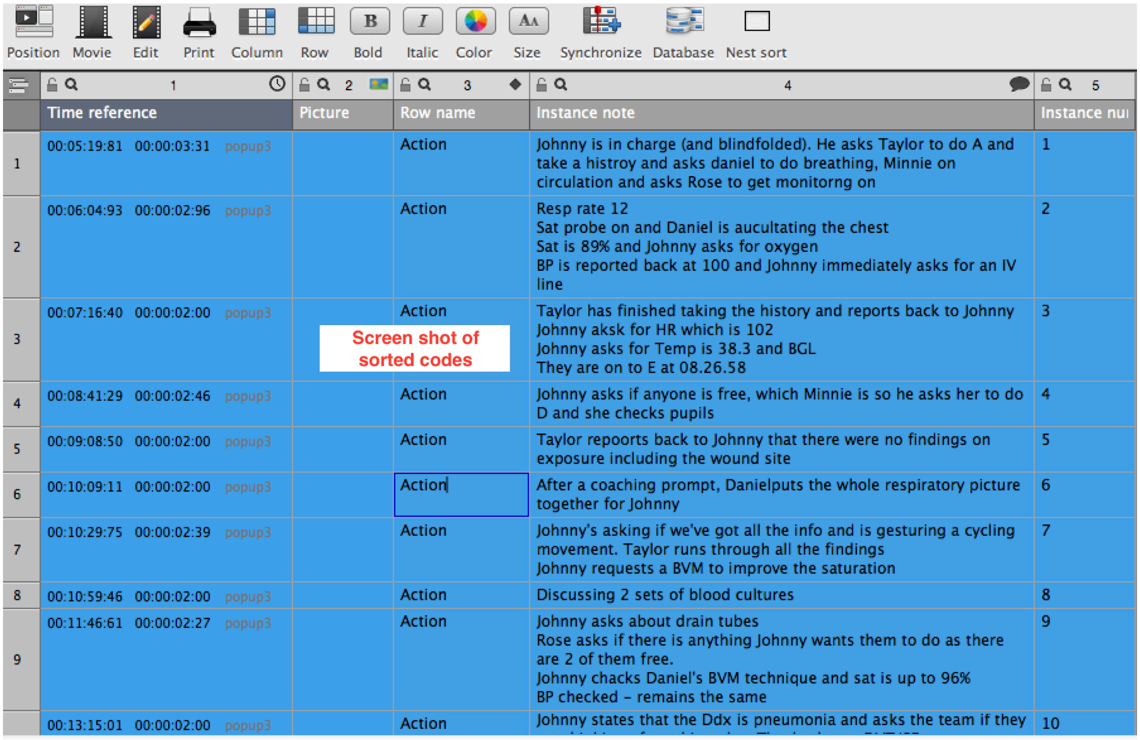

Figure 25. Example of a Studiocode® Code Sorter.

From a teaching perspective, a return to the cognitive apprenticeship model provided the basis for coding the coaching. What types of coaching activities were required to support learning and how did they change over time? Additionally, what other scaffolding was utilised and subsequently faded? Deductive coding in this instance matched coaching actions to the cognitive apprenticeship model while inductive coding led to identification of themes not included in that model. McKenney and Reeves (2012) support employing both inductive and deductive data analysis techniques in educational design research. Deductive data analysis requires analysing the data from the perspective of the conceptual framework upon which the intervention is based (in this case, Loop 1 and 2 learning). Inductive data analysis involves exploring the patterns that emerge from the data (in this case, activities required to support achieving successful Loop 1 and 2 completion; e.g., effective teamwork)

From here it was possible to develop two interpretive frameworks to ‘make sense of the complexity and messiness of classroom events’ (van den Akker et al., 2006, p. 30):

1. A framework for interpreting the evolving classroom learning environment (coaching and teamwork)
2. A framework for interpreting student learning and reasoning (Loop 1 and 2 learning).

2.5.2.2 Field notes

Field notes were both descriptive and reflective. Initially, there was a focus on describing elements within the simulation activity, but over time, both as patterns started to emerge, and based on my own extensive experience as a simulationist, the notes became more reflexive in nature. Process coding (Miles et al., 2014) was used to describe participant action/interaction and consequences. Despite initial concern that the field notes would not add any value to the study, they were in fact referred to continuously during subsequent data processing and were able to verify subsequent analysis.

2.5.2.3 Focus group interviews

A more participant-focused form of coding, ‘in-vivo’ coding (Saldana, 2014), seemed appropriate for the focus group interviews in order to more closely understand the participants’ world. Codes were based on the actual language used by the participants in order for significant or summative words or phrases to stand out. Using the natural language of the participants also enables them to contribute significantly to new knowledge (Saldana, 2015).

All focus group interviews were transcribed verbatim by hand from the video-recordings in order to create text data. Colour coding was used to identify similarities in student comments both within and between groups, and to identify patterns and themes from those codes. This inductive approach narrowed the data into specific patterns linked to the research questions along with additional unexpected themes. Patton (2015) identifies these as the questions that were conceptualised in the design phase of the study and the subsequent analytical insights that emerge from the data. Patterns were then layered (Creswell, 2014) through first- and second-layer abstraction to become the final interpretative themes of the data.

2.6 The role of the researcher

In this fieldwork, I tactically adopted the role of participant and observer as I was the coach in the simulations as well as the researcher. My predominant role was that of coach, and such is the focus of that role that, armed with the knowledge that the sessions were being video-recorded for data collection, I was not overly concerned about recalling and remembering events at a later date. In fact, I would have found it challenging to do so due to the fully immersive nature of coaching. Over the course of the second-year program, the students had less reliance on me as their coach as their expertise developed, and thus my position changed. Patton (2015) describes this shift as a 'participation continuum' (p. 336), ever-changing during the course of a study. This highlighted the importance of acknowledging the intimate relationship between the researcher and what is studied and the 'situational constraints' that shape the inquiry, as described by Denzin and Lincoln (2007, p. 10). The risk of me inadvertently coaching the research groups differently to the other groups was ameliorated by selection of the research sample group at the completion of the second-year simulation program. This risk was not present in the fourth-year simulations as a coach was not present in the room during the simulations. Further discussion on the particular details of each simulation is contained in the next chapter.

I subsequently conducted semi-structured interviews in order to question, probe, and listen to the students' perspectives in order to get closer to the meaning of their experiences and the value they placed on the cognitive support provided in the simulations. It was important to understand the coaching role through their eyes. An essential element of the interview was the acknowledgement of the participants as co-constructors of knowledge. According to Stake (1995), interviews respect the influence of the participants on the research and treat them as experts instead of simply a source of data for analysis.

2.6.1 Reflexivity

There is a requirement for the qualitative researcher to operate from a position of reflexivity throughout the entire study (Patton, 2015). This means acknowledging they were present in the world they are researching, that they bring with them to this world their own assumptions and views, and that this presence can have a dynamic impact on the study (Cleland & Durning, 2015). In this study, it could be argued that the dual roles I undertook – that of both coach and researcher in the simulations – were incompatible. For example, students may have had a reluctance to question or comment during a simulation if they felt they were being assessed as part of subsequent data analysis, thereby losing a learning opportunity. They may also have been suspicious about the amount of in-game support they were receiving if they thought that may affect outcomes. I was conscious of reinforcing from the beginning of the program that I was unaware as to which groups would eventually make up the sample group.

Also, some students may have felt extra scrutiny due to the recording of events, and this may have inhibited their ability to speak up and ask questions. Students may have also felt that subsequent viewing of the recordings would further highlight any perceived performance issues and that these could be criticised in the eventual research findings. I was mindful of these issues and during the simulations I encouraged questions and dialogic interaction the same way I had previously done as a simulation instructor. I also took care not to remind students about the video-recording at any stage and in fact felt reasonably sure they were not conscious of it occurring as they never mentioned it. From my own experience teaching medical students using simulation (12 years), the students performed in the simulations at a typical second-year level. Every effort was made to distance the research study from the simulation program.

In the focus group interviews the issue of power was a central consideration, in particular the fact that the discussion was one of knowledge construction in simulation and students may have felt disempowered to criticise or comment negatively on the simulation experience. I was conscious of how this power hierarchy could influence the interactions within the context of the discussions and tried to share the power by creating understanding through engaging in dialogue rather than directing the interview in a particular direction. As I had spent much time and effort building a trustworthy relationship with the students over the course of the simulation program, I also felt they were able to be frank and honest with me.

2.7 Rigour

2.7.1 Validity and reliability

The traditional quantitative criteria of internal and external validity are replaced in qualitative research by such terms as trustworthiness and authenticity (Patton, 2015). Lincoln and Guba (1985) posit that trustworthiness involves establishing credibility, transferability, dependability, and confirmability. Credibility is analogous to internal validity and relates to the 'truth' of the findings. Credibility is enhanced in educational design research by prolonged engagement during intervention testing (McKenney & Reeves, 2012). In this study, the engagement with the interventions was both in 27 simulation coaching sessions and in 30 hours of recorded classroom activity over nearly three years. Credibility is also about providing assurances about the views of both the participants and the researcher fitting together to provide balance, which was evidenced in this study by the focus group interviews (Patton, 2015). Analyses of video recordings in parallel with focus group interviews conformed to this demand.

Transferability has parallels with external validity and shows that the findings can be informative in other contexts. In this study that would mean the findings regarding specified learning processes and the means that have been identified to support that process, both of which could be tested in subsequent studies in a variety of settings. Concepts underpinning the research outputs of this study could also be applied across other domains such as nursing.

Dependability, or reliability, focuses on the transparency of the researcher's processes, which should be logical, traceable, and documented as described in the data collection, management, and analyses sections of this chapter and the following two findings chapters. By providing an audit trail (Lincoln & Guba, 1985) in qualitative studies, the researcher can provide documents that have been created, retained, and are accessible. In this study, comprehensive records have been made of all aspects of the research process: plans, drafts, notes, reflective notes, timetables, video recordings, coding data, and field notes. Video-recordings have been coded and stored, and all codes are time stamped on the recordings for potential data verification.

Lastly, confirmability, similar to objectivity, is concerned with the credibility of the analyses – linking the researcher's assertions, findings, and interpretations to the data in obvious ways as evidenced in Chapters 5 of this study.

2.7.2 Triangulation

Triangulation refers to the goal of seeking at least three ways to verify data and acts as a way to strengthen the validity of a study through corroboration (Yin, 2011). In this way, the weaknesses in one data source are counterbalanced by the strength of another (Miles et al., 2014). In this study, a range of qualitative data were collected from different sources – both the researcher's and participants' interpretation of events – in different forms and at different times. Patton (2015) describes triangulation as a 'test of consistency' (p. 317). In this study, qualitative data is strengthened through quantitation of coaching data analysis, which provided further understanding of the level of cognitive support required by learners in simulation.

2.8 Summary

This chapter has outlined and justified the methodological choices selected to underpin this research and the methods that have supported the methodology. Sample group selection and ethical issues have been explained and the simulation program described in detail. Video-recording of three groups of medical students, complemented by focus group interview data and field notes made up the dataset and offered a rigorous study of learning from the perspective of the researcher and the participants. Important concepts of reflexivity and research rigour were also addressed. A variety of inductive and deductive coding methods were applied to the data for the purposes of analysis, which will be presented in the following two chapters. Chapters 3 and 4 identify and describe the learning progression of three groups of second-year students as they complete a year-long simulation program and then return as final-year students 18 months later for further simulations.

Chapter 3: Findings – Learning, transfer, and retention

3.1 Introduction

Educational design research, discussed in the previous chapter, is conducted in order to design and test interventions that solve problems in practice through the development of creative approaches to learning and teaching while also constructing a set of design principles to guide future refinement (McKenney & Reeves, 2012). Two interventions were designed and implemented to support learning: a revised simulation curriculum and the creation of a new facilitation role.

The research questions listed in section 2.1 are set within the design research paradigm as outputs that measure the effectiveness of the interventions. The research questions are based on a practice-driven need to conduct a study aiming at improving teaching and learning in medical simulation, in particular at second-year level. Documentation of groups' learning processes and progress provided the empirical grounding for analysis. Examples are provided that illustrate the general assertions made from the analysis. Each example states the group or student name, the simulation number (simulation is abbreviated to 'sim') and, if applicable, a time stamp indicating when the action occurred. These outputs are presented as findings over two chapters. Learning resulting from the curriculum intervention is presented in this chapter, followed by an analysis of the coaching intervention in Chapter 4. Additionally, student reflections on both learning and coaching will also be highlighted in Chapter 4. Due to the longitudinal nature of the simulation program, repeated opportunities for practice enabled skills to be learnt and developed over time. The *process* of skill acquisition and application in relation to the two interventions introduced into the simulation program forms the basis of this chapter. According to Salas, Rosen, Held, and Weissmuller (2009), 'If performance is conceptualised and measured as a process and this aids in performance measurement goals of diagnosis and intervention, then there is the underlying assumption that by improving process, outcomes will also benefit' (p. 353).

Successful completion of both Loop 1 and Loop 2 activities described in Chapter 1 depends on three essential and interdependent factors happening in concert:

1. Adherence to the appropriately sequential components of Loop 1 and 2 frameworks
2. A teamwork dynamic that drives organised action
3. Appropriate coaching that identifies and provides suitable scaffolding.

The findings focusing on learning will be reported from the perspective of the revised curriculum – the *taskwork* skill sets deemed necessary for satisfactory completion of Loop 1 and Loop 2 patient management frameworks constructed as taskwork frameworks over the course of the simulation program. In this study, taskwork refers to the specific steps and technical skills associated with a particular job (Krokos, Baker, Alonso, & Day, 2012). Taskwork frameworks are tested for their utility by using them to assess student learning. It is important to note here that the actual frameworks themselves are based on pre-existing approaches to clinical deterioration and to clinical reasoning. The curriculum intervention under analysis is the structured way in which both the learning loops are repeatedly applied in every simulation and the somewhat artificial initial separation of the loops to ensure completion. This is done to promote automation of Loop 1 steps, regardless of the clinical circumstances, and to manage cognitive load during the learning phase. During analysis it became evident that successful patient management was reliant on effective *teamwork*. Teamwork is the *process* of enacting teamwork competencies such as the knowledge, skills, and attitudes that are necessary to function as an interdependent team (Salas et al., 2012). Examples of how teamwork affected group performance during the simulations, and the critical role that teamwork attributes play in effectively developing team cognition traits, are also described.

Evidence of *transfer and retention* of learned skills will be presented through the analysis of pop-up simulations, described earlier in Chapter 2, at the completion of the formal second-year simulation program, and lastly, fourth-year simulations conducted after an 18-month student break from both simulations and from acute adult medicine.

3.2 Learning

3.2.1 Taskwork

3.2.1.1 Loop 1: Clinical deterioration

As discussed in Chapter 1, section 1.2.1, the taskwork skills represented in Table 14 are considered generic to all patients requiring initial stabilisation prior to ongoing management, despite the cause of their deterioration. This framework is a standardised representation of the structured approach taught to students and therefore applicable to all of their simulations. Each letter of the DRSABCDEFG framework has corresponding steps, and within each step there a number of components that need to be completed. The steps are sequenced according to the threat to life. For example, if the student does not recognise the danger of the situation (D), then his or her own life might be at risk. This is especially so in the pre-hospital setting where road traffic or other hazards may be a problem. Moving on from there, A (airway) is the next most important step as the airway needs to be clear for breathing (B) to occur and so on.

Action frameworks have been developed for both Loop 1 and Loop 2 learning and assessment. The frameworks were developed as part of this research in order to deductively code student actions in a logical way for subsequent analysis. A basic form of cognitive task analysis was adopted in order to document the tasks that required completion during clinical deterioration and clinical reasoning, and from there develop an aid to support data analysis. Cognitive task analysis is the 'study of cognition in real-world contexts and professional practice at work' (Crandall et al., 2006, p. vii). The process of cognitive task analysis includes presenting data and findings, and explaining meaning (Crandall et al., 2006). As a result of this process, the frameworks form the basis for learner actions and thus act as a platform for deductive coding. As a separate function, the frameworks can subsequently be used as coaching aids to predict and analyse learner actions. Although the frameworks do not capture what students are thinking about at the time of a particular action, combined with appropriate and timely coaching strategies, such as articulation, cognition can be explored to complement action.

The Loop 1 framework (see Table 14) is a linear representation of a cyclical process. Students are expected to progress through steps in the described sequence (column 2) and complete all of the component skills that accompany each step (column 3). The framework thus forms the 'ground rules' of patient assessment and stabilisation for novice learners in the setting of clinical deterioration. The content of the frameworks was based on the clinical school's medical faculty's expertise in 'best practice' standards of patient care appropriate for the level of a junior doctor. The final designs of all frameworks were validated by a senior medical clinician experienced in simulation-based learning.

Repeated practice with attention to every step provides opportunities for students to apply the ground rules in a variety of contexts. The application of these rules is an example of 'near transfer' tasks with an associated expectation that they are applied in a similar way every time they are performed (Clark et al., 2006). As expertise develops, and students become more familiar with differing patient presentations, the steps can be particularised to a situation through prioritisation resulting in an eventual merging of Loops 1 and 2 in action.

A description of various findings, or results, is listed in column 4. This framework was used as a data collection tool for each of the groups' six simulations and therefore the basis for inductive coding. As each component of the steps was completed and a corresponding action undertaken, a time stamp was applied to track progress through the simulation (see Appendix E for an example). From that data, a chronological timeline was also created to demonstrate a clear picture of task prioritisation (see Appendix F for an example).

Table 14. Loop 1 taskwork skills table

1. Step	**2. Sequence**	**3. Step components**	**4. Findings and actions**
D	Assess danger	Check for danger	NB Assumption of no danger in every simulation
(Intro)	Commence patient interview	Introduce self to patient	
R	Assess patient's response in the correct sequence	Ask orientating questions about person, time, and place, OR	Orientated
		Assess response to	Disorientated and/or drowsy

		voice, OR	
		Assess response to pain	If not responding appropriately - send for help
S	Send for help	As and when required	Send for help at any stage of the DRSABCDEFG assessment as required
A	Assess airway	Examine mouth	Note airway oedema or obstruction. Suction if required
		Listen for airway noises	Recognise normal airway
			Note type of sound tachypnoea
			Use airway manoeuvres and adjuncts if appropriate
			Unable to clear or manage airway – send for help
B	Assess breathing	Count respiratory rate and observes for symmetry, work of breathing, and pattern	Recognise normal respiratory rate
			Recognise hypoventilation/tachypnoea
			Recognise asymmetry
			Recognise abnormal pattern
			Assess work of breathing tachypnoea
		Auscultate lungs	Note presence or absence of sounds and percuss if absent
			Note normal or abnormal sounds
		Apply probe to measure oxygen saturation	Recognise normal oxygen saturation
			Recognise hypoxia and commence appropriate oxygen therapy if required
			Recognise hypoxia and commence inappropriate oxygen therapy
C	Assess circulation	Note skin colour, skin temperature, and/or diaphoresis	Note normal
			Note cool/warm
			Note pale/flushed
			Note clammy/sweaty
		Observe heart rate on monitor	Note normal heart rate
			Note abnormal heart rate
			Note irregular waveform
		Palpate radial pulse and note pulse	Note normal heart rate
			Note abnormal heart rate

		character	Note regular/irregular
			Note bounding/normal/thready
		Measure blood pressure	Recognise hypotension/normotension/hypertension
		Check mucous membranes	Note dry or moist
		Assess Jugular Venous Pressure	Recognise low/normal/elevated
		Check capillary refill	Note speed
		Perform 3-lead Electrocardiogram	Recognise heart rhythm
		Recognise abnormalities and inserts intravenous cannula if required	Recognise fluid overload tachypnoea
			Recognise hypovolaemia and commence appropriate intravenous fluid replacement
			Unable to correct hypotension/hypovolaemia – send for help
D	Assess neurological disability	Check pupils	Recognise normal pupils
			Recognise pupil abnormality
		Test limbs	Recognise normal limb movement/strength
			Recognise abnormal limb movement/strength
			If neurological deficit detected – send for help
E	Expose patient	Perform top-to-toe examination front and back	Identify normal examination
			Identify abnormal skin condition, oedema, inflammation, rash, scars, infection, surgical sites Examine the abdomen
		Measure core temperature	Recognise normal body temperature
			Recognise hyper-/hypothermia
FG	Don't ever forget glucose	Measure blood glucose level	Recognise normal blood glucose level
			Recognise hypo-/hyperglycaemia
			Administer glucose if hypoglycaemic

It should be noted that this framework differs slightly from other similar frameworks used in the setting of clinical deterioration. In particular, when an RRT or a MET is called to the bedside, the framework used by those teams is less detailed in some components and more detailed in others. Being experienced clinicians, these team members have expertise that allows them to identify patient abnormalities more intuitively (i.e., without such thorough patient data collection) through strategies such as pattern recognition. As a result, they rely less on automaticity and more on their well-developed mental models of the situation. As discussed in section 1.3.1, associations of signs and symptoms generate patterns that experts quickly recognise but that have little meaning for students. Additionally, once they do prioritise abnormalities, experienced clinicians have a larger range of choices to address the problems than novice medical students. Until such expertise develops, a more 'algorithmic' approach means the basics are not overlooked by novices. In fact, in the setting of clinical uncertainty, experts also revert to this basic structured approach in order to collect all available information and to ensure they have not overlooked anything (Schwartz & Kostopoulou, 2019).

The following systematic guidelines for *novice* learners when using this approach are thus as follows:

1. **Move through each step sequentially.** This is due to the interdependence of some steps (such as A for airway and B for breathing – the airway must be clear for breathing to occur), and to the risk to life associated with each step (e.g., if the airway is not clear and the patient cannot breathe, then the blood pressure is irrelevant), and finally to ensure that nothing is overlooked.
2. **'Fix as you go'.** In order to stabilise the patient and move to the next step, the current step must be first addressed and any deranged physiology rectified if possible. If it cannot be rectified, then more senior help must be called. For example, if the airway is obstructed, it must be cleared before breathing can be assessed. Additionally, there are 'if-then' type rules: 'Given situation X (low oxygen saturation), action Y will be taken (apply high-flow oxygen), and situation Z (increased oxygenation saturation) will be the outcome.
3. **Continue to regularly recycle through especially if anything changes.** For example, if a previously clear airway (A) becomes noisy, which indicates it is obstructed, then it must be reassessed and cleared. All vital signs such as heart rate and blood pressure should be rechecked on a regular basis. Continued recycling is diagrammatically represented by the cyclical design of the action-cue cognitive aid poster (see Figure 3, Chapter 1 for representation)

Second-year cases

Second-year cases typically ran in the following way, with the coach introducing the patient in a pre-briefing:

> *Mr Smith is a 68-year-old man who has become pale, sweaty (often indicates low blood pressure) and tachycardic (fast heart rate) after a total knee replacement 4 days ago. Could you please assess him?*

The group should appoint a leader who allocates roles based on the DRSABCDEFG approach (Loop 1), collect information, and initiate treatment to stabilise the patient (in this case, correct the low blood pressure, which in turn will most likely correct the fast heart rate). Students then move in to clinical reasoning mode (Loop 2) to investigate the cause of the low blood pressure and fast heart rate in the first place. Clinical props such as a patient monitor, blood test results, and X-rays are available to the group. The in-game coach offers guidance, advice, and prompts and provides scaffolding, as described earlier, to assist students to complete the case.

Analysis of Loop 1 findings derived from a process of inductive data coding, are presented in the following three sections based on the above guidelines addressing the *process* of completing the loop, followed by analysis of *learning progression* as expertise developed.

Process (adherence to the aforementioned systematic guidelines for novice learners)

1. Move through each step sequentially

From the perspective of the systematic guidelines, the analysis indicates that in the early simulations the second-year groups did move through each Loop 1 step sequentially. This was especially so when the Loop 1 action-cue poster was present, and groups often referred to the poster as they progressed through the case. Some components of the steps were omitted at times, but in the main, and with appropriate coaching, the majority of the important and relevant steps were completed. Twenty per cent (20%) of all Loop 1 coaching episodes were directed at prioritisation and completion of Loop 1 steps.

The action-cue poster was utilised by teams until they decided they no longer needed it – this usually occurred around the time of simulation number three or four. Group 2 decided to remove it somewhat prematurely at simulation two. Having not appointed a leader in simulation one, they had great reliance on the poster as 'de facto' leader and in fact turned to it for guidance on nine occasions in the first 1 minute of the simulation (Group 2, Sim 1, 14.37; Group 2, Sim 2; Group 2, Sim 3).

On several occasions across all groups, rather than Loop 1 steps being undertaken proactively, they were in response to some other prompt, such as an earlier patient finding or a patient response. For example, a 3-lead ECG (heart trace monitor) was not routinely performed as part of circulation but was applied as a reaction to the patient complaining of chest pain (Group 1, Sim 1, 19.28.29), or an intravenous cannula was inserted because blood tests were required (Loop 2 activity) rather than inserted as part of the circulation assessment (Group 1, Sim 2, 16.09.82). In other words, the process of completing the cycle was not automated and proactive, but rather as a response to prompting, either from the coach, the patient, the findings, or by the poster. In contrast, in later simulations, it was as if students had learnt or appreciated the value of routinely completing all steps such as always siting an intravenous cannula as a precaution whether or not the patient required intravenous fluids (Group 2, Sim 6, 14.54.54).

As the Loop 1 process became more automated with repeated practice over time, the number of coaching episodes required to support completion of Loop 1 steps reduced to the point where an average of only two coaching episodes were necessary in the last two simulations for each group (Group 1: 3 and 0 episodes, Group 2: 3 and 1 episodes, Group 3: 3 and 2 episodes).

2. Fix as you go

The fix-as-you-go rule was not immediately evident in the early simulations, especially in relation to the circulation assessment. It appeared that groups were more focused on completing the cycle in its entirety and then thinking later about how to approach any deranged physiology. It needs to be reinforced here that, as discussed in section 1.3.2 of Chapter 1, treating ('fixing') a patient prior to making a definitive diagnosis is a foreign concept to medical students and is in stark contrast to traditional medical practice. This manifested in one of three ways:

(a) The abnormality was noted but not addressed. Example: A team member observed a very low respiratory rate (a crucial finding) in a patient with low blood oxygen saturation and an obstructed airway but did not report it back to the team leader (Group 2, Sim 4, 16.31.52). A second example was one of low blood pressure where it was measured but not commented on for 4 minutes. At that point hypotension (low blood pressure) was recognised but not addressed until all remaining Loop 1 steps were addressed, which was a further 10 minutes later (Group 1, Sim 2, 16.33.34). This is in contrast to a later simulation where hypotension was recognised and addressed immediately (Group 1, Sim 5, 08.36.00; Group 2, Sim 6, 09.00.28).

(b) The abnormality was not noted. Example: A 3-lead ECG was applied to a patient with chest pain, but the trace (showing heart attack) was not noted (Group 1, Sim 1, 19.32.44).

(c) The abnormality was noted but not considered abnormal. Example: The team leader described the patient's status and commented that the blood pressure was normal when in fact it was very low (Group 1, Sim 2, 16.07.05).

The most challenging step for each group was the complexity of the circulation assessment. Not only does it have the greatest number of components, but also, unlike the other steps, there are a number of assessment outcomes that can vary depending on just one crucial finding – in other words, it has high-element interactivity. In the main, a low blood pressure and high heart rate often indicate low cardiac output (the amount of blood the heart is pumping in each beat). If this is due to not enough blood in the body, then intravenous fluids are indicated to replace volume; however, if the reason is that the heart itself is failing, then intravenous fluids may need to be considered more judiciously, and the heart may struggle more if excessive fluids are administered. For this reason, the circulation assessment needs to be made after considering all circulation findings as just one finding may affect management. In every simulation, heart rate and blood pressure were measured very early in the case, and the subsequent circulation assessment was based on these findings alone. Complementary findings such as jugular venous pressure (JVP; observable pressure in a neck vein indicating possible heart failure), capillary return (how quickly the blood returns to a finger after an occlusion is released, which may indicate poor blood flow to the area), and mucous membranes (dry mucous membranes may indicate dehydration) were only completed with coaching support (Group 3, Sim 1, 17.49.04; Group 2, Sim 2, 13.22.33; Group 2, Sim 1, 34.51.90).

Of particular note was the omission of a 3-lead ECG heart monitor from the circulation assessment. This was crucially overlooked on three occasions when the patient was experiencing a heart-related problem and resulted in an important piece of information being omitted from the overall assessment (Group 1, Sim 1; Group 2, Sim 1; Group 3, Sim 3). In the early simulations, it was almost as if the groups were using the Loop 1 cycle as a 'tick box' where steps would be completed but the outcome went unnoticed (Group 1, Sim 1, ECG findings, 19.32.44; Group 3, Sim 2, low oxygen saturation, 05.00.86). In comparison, deranged findings that were 'standalone' (such as blood glucose level, or BGL), rather than a combination of many factors requiring synthesis (such as circulation), were usually fixed immediately or noted for future reference.

From a breathing assessment perspective, low oxygen saturation fared better. Once students had been reassured in the early simulations that high-flow oxygen was required to address low blood oxygen saturation, they were able to put previously learned apprehension about the risks of administering oxygen to one side and it was subsequently well managed. High-flow oxygen can be detrimental in particular situations such as a patient with chronic respiratory disease or a patient having a heart attack or stroke. However, on arrival at the bedside it may not be apparent that the patient has these particular conditions, so students are taught that if the oxygen saturation is lower than normal (for that patient), then they must commence high-flow oxygen while they complete an initial assessment. The dose of oxygen can then be modified once differential diagnoses have been formulated that may include one of the aforementioned conditions.

3. Continue to recycle through

Despite the cyclical representation of Loop 1 steps on the poster, students often approached Loop 1 in a linear fashion and considered it 'complete' when they got to FG. Nine per cent (9%) of Loop 1 coaching episodes were focused on reminding students to recycle through Loop 1 to ensure the patient remained stable. Again, on completion of Loop 1 steps, it appeared that groups 'ticked that box' and moved on to Loop 2 exclusively, rather than continuing to concurrently recycle through pertinent Loop 1 steps. In the early simulations, when groups did recycle, it took one of two forms. First, the Loop 1 steps were strictly adhered to, to the point where initial findings that were highly unlikely to change within the time frame, would be rechecked unnecessarily. An example of this is rechecking the BGL regularly when it had been initially normal and there was no change in the patient status to indicate that it needed rechecking. In other words, students were unable to prioritise what needed rechecking. It was almost as though students were over-dependent on the action cues on the poster rather than thinking about what was likely to change in a particular patient over time. Second, the recycling would only occur in response to a trigger, rather than being a regular activity. For example, once the intravenous fluids had finished infusing, the blood pressure would be checked, rather than checking it during the infusion to see whether the infusion was having the desired effect or not. Recycling became more automated in the later simulations (Group 1, Sim 5; Group 2, Sim 4).

Learning progression

The guidelines for patient stabilisation can vary somewhat as learning and expertise develops, as described earlier in this section in reference to METs. For example, if the initial patient presentation were an alteration to the conscious state, then it would be acceptable to measure BGL earlier than the framework suggests. A low BGL is one cause of altered consciousness and something that needs to be corrected quickly. This is an example of how medical students' approaches to initial patient stabilisation may change over time as they become more experienced with the application of the guidelines; in other words, appropriately adjusting the guidelines to meet the needs of the patient. However, it is essential that medical students initially learn the sequence in order to ensure that crucial steps are not overlooked. The risk for novices is that they immediately address blood glucose without returning to the start of the cycle to complete the other steps.

Somewhat artificially in the early simulations, students are expected to complete Loop 1, even if they have a reasonable idea of the diagnosis. Ensuring rigid adherence to the cycle and prevention from entering Loop 2 prior to Loop 1 completion is one of the roles the coach. This is especially so in the early simulations when student enthusiasm for making the correct diagnosis often threatens satisfactory completion of Loop 1 steps. For example, although the aforementioned low BGL is a threat to life if not treated quickly, in simulation time is not a factor. In other words, the patient will stay in a low BGL 'holding pattern' until the group first completes the other steps. Over time, especially as effective teamwork strategies develop, prioritisation of the order of the steps along with merging of the loops occur as teams are able to complete Loop 1 while simultaneously managing Loop 2. As described in section 1.4.4, this is indicative of a move towards more expert practice.

Apart from these patient-centred minor alterations to the order of the steps in the DRSABCDEFG framework, it does not alter over time. It is therefore important to note that the students are not expected to demonstrate sequential application of the steps over time (i.e. apply steps D and R in the first simulation, then once they are satisfactorily completed, move on to A and B in the next simulation). All steps are expected to be completed in every simulation and repeated as required.

Therefore, from a *learning progression* perspective, anticipated changes to student performance over time in using these guidelines would be:

- **improvement in timeliness and efficiency** in the completion of each component of each step in the Loop 1 cycle so that clinical deterioration is addressed with the least waste of time and in a competent manner, and
- **prioritisation in the order of Loop 1 steps** depending on the context of the situation.

1. Timeliness and efficiency

Unstable patients are often time critical, resulting in a situation that is usually stressful for those involved. Students were aware that the stress of time pressure had been deliberately removed from the simulated situations, and indeed, as mentioned, the patient-mannequin could be kept in a 'holding pattern' of abnormal physiology without any risk of deterioration while students learnt structured patient management approaches. Although not strictly accurate as some components of the steps were initially overlooked and rectified later, in the early simulations, groups took about 10 minutes to complete Loop 1. In the main, circulation was not fully assessed within that time, but the two major circulation findings of blood pressure and heart rate were always measured. By the final simulations, times to complete Loop 1 were down to 4 minutes for Groups 2 and 3, and 9 minutes for Group 1. There was a lot of time variation both within and between the groups from simulations one to six. Group 1 consistently stayed around the 10-minute mark, Group 2 struggled in the middle simulations with poor leadership and twice took about 20 minutes to complete Loop 1, and Group 3 took between 5 and 7 minutes each time. Group 1's consistency in completing Loop 1 in 10 minutes was due to their thoroughness in completing all of the steps prior to merging into Loop 2. For example, Group 1 always assessed response by asking orientating questions, whereas Groups 2 and 3 only assessed response if the patient had appeared confused when the student first introduced him- or herself. In other words, checking response was only as a reaction to an initial answer by a patient rather than as a routine examination. It must be noted that, as described in Chapter 2, groups were undertaking differing clinical rotations, so the order in which specific cases were simulated varied for each group. For that reason, the amount of work required to complete Loop 1 was not consistent across the six simulations. Additionally, as teamwork expertise developed, more time was spent in Loop 1 discussing findings and planning actions. Therefore, the taskwork aspect of Loop 1 sped up but the overall time taken did not always decrease as more time was taken up with team communication.

Turning now to efficiency, two factors changed over time. First, in role allocation, team leaders changed from allocating components of steps to allocating entire steps. An example of 'component allocation' was individual components of the step of assessing breathing being allocated to individual students, such as one student counting the respiratory rate and another listening to the breathing.

Example:

> *Lauren (to team leader): 'So we've got bilateral breath sounds with no added sounds.'*
> *Johnny (team leader): 'What's the resp [breathing] rate – James can you do the resp rate?'* (Group 1, Sim 1, 07.45.88)

In this case, two students were undertaking components of the one step (breathing). This results in both staggered information being received by the leader and individual students being potentially unaware of complementary results. Patient findings are therefore not synthesised to gain an overall picture of the breathing. As efficiency improved, leaders were allocating steps in their entirety so that one student would assess all the components of breathing and report findings back to the leader as a whole.

Akshay (team leader): Guy, you're on A and B.
Guy (after examining the patient and noting low blood oxygen saturation): So Akshay, resp rate is 30 and lung fields are clear ... I'm just going to put this [oxygen] mask on you Freda [patient] to help you breath, ok? (Group 3, Sim 6, 09.04.90)

In this example, Guy is allocated A and B and not only reports his findings back to Akshay but also automatically initiates treatment of the low blood oxygen saturation with oxygen therapy. Applying DeWitt et al.'s (2008) adapted RIME framework to this situation, Guy has progressed from solely reporting findings back to Akshay to interpreting the data correctly (low blood oxygen) and implementing correct management (oxygen therapy).

Over time, Loop 1 steps were also completed simultaneously, so instead of one student completing A, followed by another student completing B (Group 3, Sim 1, 07.50.74), these were occurring at the same time, which obviously decreased the time it took to complete the cycle. Prior to this happening, groups would become fixated on one step with all members addressing a particular problem and no one moving on to the next step. An example of this was when the entire group was trying to manage a problem with the airway rather than having one person allocated to that role while the others completed the remainder of the cycle (Group 3, Sim 1, 08.35.88).

2. Prioritisation of steps

As mentioned earlier in this chapter, rigid adherence to the Loop 1 steps in simulation ensured that important findings were not overlooked. However, this is somewhat artificial compared to a real patient encounter where more experienced clinicians using pattern recognition may alter the order in which they address patient issues. The risk for novice learners in attempting this is that by prioritising one step, preceding steps are totally overlooked. As groups became more proficient at all of the Loop 1 steps, it was evident that they were able to prioritise more effectively, and at times steps were completed out of order depending on the context of the case. For example, a patient with abdominal pain had their abdomen examined much earlier in the case (as was appropriate) instead of waiting to complete DRSABCD before getting to E (where abdominal examination usually sits). While this was happening, other students completed the cycle in order (Group 3, Sim 2, 15.03.43). A second example of this was demonstrated when a team leader divided the group into two smaller teams in order to simultaneously complete Loop 1 steps and address urgent Loop 2 findings (Group 1, Sim 4, 27.06.22).

As a coach, it was initially challenging to manage the tension between allowing students to progress unaided in order to discover something for themselves versus supplying 'just-in-time' coaching that guided the process and ensured nothing was overlooked. In other words, identifying what can be achieved by the students in an iterative manner and which steps require intervention in order to succeed. Analysis of the video recordings has identified areas of Loop 1 that were frequently challenging for all groups to complete, such as a thorough circulation assessment, and can be used as a basis for the development of future coaching guidelines. Recurring critical points requiring coaching in Loop 1 are summarised in Table 15.

Table 15. Critical points requiring coaching episodes

Step	Sequence	Critical points requiring coaching events	References
D	Assess danger	N/A	
R	Assess patient's response in the correct sequence (AVPU)		
S	Send for help	On five occasions, groups needed coaching assistance to decide whether or not a call for help was required	Group 1, Sim 3, 18.18.01 Group 2, Sim 2, 07.39.53 Group 1, Sim 4, 35.12.52
A	Assess airway		
B	Assess breathing	Breathing was always thoroughly assessed, but there was initial reluctance in the early simulations to administer high-flow oxygen. Once students overcame this fear, oxygen was always applied as soon as low blood oxygen saturation was detected. In two cases, anaphylaxis and altered conscious state, where the breathing was more of a challenge than in other cases, all groups required extra coaching. 16% of all coaching was to do with breathing and oxygen delivery.	Group 2, Sim 4 x 3 events Group 1, Sim 4 x 4 events

C	Assess circulation	There were 30 coaching episodes (30% of all coaching) related to circulation (the highest number of episodes). Often, the circulation assessment was based on blood pressure and heart rate only rather than all the steps in C. On most occasions, students recognised low blood pressure; however, treating it immediately with IV fluids was not a priority (not 'fixed' as they went) and was addressed at the completion of all Loop 1 steps. The other common challenge was working out IV fluid volume and rate. Coaching consistently provided a set of rules to work this out, which were often utilised. In later simulations, low blood pressure (and the need for IV fluids) was eventually managed but was often delayed due to groups becoming distracted with Loop 2 activities.	Group 3, Sim 1, 18.54.96 Group 3, Sim 5, 26.18.28 Group 1, Sim 2, 33.31.88 Group 1, Sim 4, 20.41.83 Group 2, Sim 2, 13.22.33 Group 2, Sim 4, 32.46.23 Group 3, Sim 5, 25.10.32 Group 2, Sim 5, 19.03.51
D	Assess neurological disability		
E	Expose patient		
FG	Don't ever forget glucose		

Note.

AVPU = Alert, voice, pain, unresponsive

C = circulation

IV = Intravenous

Nowhere in the literature does it identify the challenges that medical students have in the application of the steps required to manage clinical deterioration. The steps appear quite straightforward, but simultaneous 'thinking' and 'doing' is also a new skill to be learnt by these students who do not get to 'do' on a real patient. There will always be differences between groups but the identification of a 'typical' learning progression through application of the learning frameworks over an extended period of time has identified specific challenges faced by medical students.

Once appropriate Loop 1 steps had been addressed to stabilise the patient, groups progressed to Loop 2 to form a diagnosis and a management plan. The next section addresses Loop 2 learning progression.

3.2.1.2 Loop 2: Clinical reasoning

This Loop 2 taskwork framework is less descriptive and more generic than the Loop 1 framework. The framework is based on Bowen's (2006) diagnostic problem-solving representation as shown in Table 16.

Table 16. Diagnostic problem-solving (Bowen, 2006)

Step	Description
1. Data acquisition	History taking, physical examination, investigations
2. Development of a problem representation	Summary of the data collected
3. Hypotheses generation	Development of differential diagnosis
4. Search for an illness script	A representation of a disease that best fits the findings
5. Refinement of hypotheses	Collecting more data and testing it against the hierarchy hypotheses
6. Diagnosis	Deciding that one hypothesis is the most likely
7. Reflection on the certainty of the diagnosis	Consider any bias (e.g., premature closure)

From a practice perspective, two added clinical reasoning steps in Loop 2 are the development of a management plan and reassessment of patient status, as seen in Table 17 (steps 7, 8, 9, and 10).

Unlike Loop 1, where each step has specific components that need to be assessed every time, the specific details of steps in Loop 2 are case dependent and therefore the actions (column 3) will also differ from case to case. The basic flow of clinical reasoning is present, again in expected order of application, such as history taking first followed by physical examination, yet the detail depends on the diagnosis. If the patient had back pain, then the back would be examined, compared to the leg in a patient with calf pain.

Subsequently, the actions depend on the particular findings. Additionally, as discussed in section 1.2.2, the cognitive processes applied in clinical reasoning vary both between clinicians and between situations, although in general students at this stage of learning will more than likely follow the linear pattern represented here in the framework. Loop 2 therefore provides opportunities for students that are more diverse in nature while still requiring them to maintain a structured framework thus promoting transfer from one situation to another. An essential component of this framework is completion of unfinished steps from Loop 1 (row 9, Table 18a). As described in Chapter 1, as mastery develops, the overlapping of the two loops becomes evident as students are able to concurrently deal with Loop 1 and Loop 2 issues as required.

Table 17. Loop 2 taskwork skills framework

Clinical reasoning categories	Steps	Case-specific steps	Learner actions
Data acquisition	**1.** Targeted history taking	A succinct and relevant history is taken + AMPLE	
Data acquisition	**2.** Targeted physical exam	A relevant and appropriate physical examination is undertaken	
Development of a problem representation and hypotheses generation	**3.** Consider differential diagnoses	Most likely diagnoses are considered	
Refinement of hypotheses	**4.** Order appropriate investigations	Appropriate investigations linked to differential diagnoses	
Refinement of hypotheses	**5.** Accurate interpretation of investigation results	Investigation results are accurately interpreted and used to refine differential diagnoses	
Diagnosis	**6.** Determine a working diagnosis	A working diagnosis is determined (this may require more	

		senior assistance)
Development of a management plan	**7.** Call for appropriate advice	Appropriate assistance is sought prior to the commencement of a management plan
Development of a management plan	**8.** Prioritise and manage immediate Loop 2 findings if appropriate	Immediate issues are addressed (e.g., antibiotics for severe infection sepsis)
Reassess patient status	**9.** Complete unfinished Loop 1 steps	Loop 1 steps are completed
Reassess patient status	**10.** Recycle through relevant Loop 1 steps	Patient status is regularly assessed and updated
Identify management issues	**11.** Identification of management issues	The coach assists with management challenges, especially in relation to protocols and medications
Reflection on the certainty of the diagnosis	**12.** Consider any bias (e.g., premature closure)	The coach prompts reflective practice at salient times during the case

Note.

AMPLE = Allergies, medications, past history, last ate/lifestyle, event

The following table (18a) represents an example of Loop 2 activity for Group 1 managing a patient having a heart attack. Two versions are displayed: medical and non-medical (18b).

Column 3 has been populated with time stamped actions the group has undertaken in managing this patient. Coaching episodes and other comments are listed in column 4. Actions are time stamped in **bold** when completed. Coaching episodes and oversights are in **red**

Table 18a: Medical version: Specific example of Loop 2 rubric for heart attack (ST elevation myocardial infarction)

1. Steps	**2. Case-specific steps (what they should do)**	**3. Group actions (what they did do)**	**4. Coaching episodes/other comments**
1. Targeted history taking	AMPLE Cardinal signs chest pain Cardiac history Back pain history	**23.30.12** Allergies checked **16.12.82** Chest pain history **19.18.95** Cardiac risk factors Back pain history taken in Loop 1	They needed to explore the back pain history and ensure that it was musculoskeletal or neurogenic and not linked to the chest pain; i.e., it wasn't *tearing* in nature and didn't *radiate* to the back as that would indicate a different diagnosis (aortic dissection)
2. Targeted physical exam	Auscultate heart	**27.15.32** Heart auscultated	
3. Consider Ddx	Acute coronary syndrome (including STEMI) Aortic dissection Pulmonary embolism Pneumothorax GORD	**13.53.63** ?Disc herniation **14.19.02** ?Septic osteomyelitis (ruled out – afebrile) **15.45.18** Discuss causes of nausea **16.15.48** Chest pain disclosed by patient **18.24.35** ?Cardiac causes or GORD **20.33.34** STEMI **29.36.85** Other Ddx discussed and ruled out and extended chest pain history taken	29.36.85 Coach prompted this discussion to cover all Ddx and prevent fixation error

4. Order appropriate investigations	Troponin/CK/FBE/UEC/Coags/LFTs 12-lead ECG Echo if considering dissection Chest X-ray	**24.30.45** Bloods ordered – FBE/U&E/troponin/CK **27.24.29** 12-lead ECG	27.24.29 Prompted by coach. They were basing their diagnosis of ST elevation on a 3-lead ECG rather than using all available information on a 12 lead
5. Accurate interpretation of investigation results	Chest X-ray Elevated troponin Elevated CK ST elevation on 3-lead ECG 12-lead ECG = Inferior STEMI	Chest X-ray normal All blood results interpreted correctly **20.46.09** 3-lead ECG findings noted **27.24.29** 12-lead ECG findings discussed, and correct diagnosis reached	
6. Determine a working diagnosis	Inferior STEMI	**33.22.55** Inferior STEMI	
7. Call for appropriate advice	MET call Cardiology registrar	**21.01.00** MET call **20.45.62** Decide to call cardiologist/catheter lab **43.56.80** Updates cardiology registrar	
8. Prioritise and manage immediate Loop 2 findings if appropriate	Morphine Oxygen Nitrates Antiplatelets	**15.08.09** Oxygen saturation has dropped so oxygen commenced **15.52.18** Organises analgesia and antiemetics (for back pain) **21.18.93** Suggesting appropriate STEMI management – morphine/oxygen/nit	

	Antiemetic After call to registrar – Heparin	rates/aspirin **23.35.77** Aspirin and nitrates administered **37.03.62** Oxygen titrated down **41.53.39** Morphine administered	37.03.62 Prompted by coach. This is really important in STEMI to not have high-flow oxygen running
9. Complete unfinished Loop 1 components	Palpate radial pulses Check tissue turgor Check capillary refill Check urine output Performs 3-lead ECG IV cannulation Examine the abdomen	**17.25.79** 3-lead ECG suggested **19.28.89** 3-lead ECG applied ECG noticed at **20.33.34** **33.40.07** IV cannulation	Abdominal exam should have been part of E in Loop 1 then considered again in a Ddx of aortic dissection
10. Recycle through relevant Loop 1 components	Recycle approx. 5 minutely especially HR/BP/saturation/3-lead ECG	**15.17.45** Oxygen saturation falls – oxygen applied via nasal prongs **19.25.42** Change to Hudson mask **25.50.15** Recycle through some Loop 1 components **28.35.15** Rechecks BP BP rechecked for first time since 08.58.20 **37.41.52** Rechecks	

		BP **40.03.41** Rechecks BP	
11. Management challenges identified	Possibly drug doses and administration	**17.39.62** Morphine dose not known **22.35.59** Nitrate and aspirin doses not known	Coach assisted with all drug routes, frequency, and doses

Note.

AMPLE = Allergies, medications, past history, last ate/lifestyle, event

BP = Blood pressure

CK = Creatinine kinase

Coags = Coagulation studies

Ddx = Differential diagnoses

E = Exposure

ECG = Electrocardiogram

FBE = Full blood examination

GORD = Gastro oesophageal reflux disease

HR = Heart rate

IV = Intravenous

LFTs = Liver function tests

MET = Medical Emergency Team

STEMI = ST elevation myocardial infarction

UEC = Urea and electrolytes

Table 18b. Non-medical version of Table 18a

1. Steps	**2. Case-specific steps (what they should do)**	**3. Group actions (what they did do)**	**4. Coaching episodes/other comments**
1. Targeted history taking	General history Major signs chest pain Cardiac history Back pain history	**23.30.12** Allergies checked **16.12.82** Chest pain history **19.18.95** Cardiac	

		risk factors Back pain history taken in Loop 1	They needed to explore the back pain history and ensure that it was muscular or nerve based and not linked to the chest pain; i.e., it wasn't *tearing* in nature and didn't *radiate* to the back as that would indicate a different diagnosis (aortic bleeding)
2. Targeted physical exam	Listen to heart with stethoscope	**27.15.32** Heart listened to	
3. Consider all potential diagnoses	Heart attack Bleeding aorta Lung clot Collapsed lung Reflux	**13.53.63** ?Lower spine disc problem **14.19.02** ?Infected bone in spine (ruled out – afebrile) **15.45.18** Discuss causes of nausea **16.15.48** Chest pain disclosed by patient **18.24.35** ?Cardiac causes or reflux **20.33.34** Heart attack **29.36.85** Other diagnoses discussed and ruled out and extended chest pain history taken	29.36.85 Coach prompted this discussion to cover all diagnoses and prevent fixation error
4. Order appropriate investigations	Appropriate blood tests 12-lead ECG (extended heart monitor trace) Ultrasound if considering aortic bleed Chest X-ray	**24.30.45** Appropriate blood tests **27.24.29** 12-lead ECG (extended heart monitor trace)	27.24.29 Prompted by coach. They were basing their diagnosis of heart attack on a 3-lead ECG (heart monitor) rather

			than using all available information on a 12 lead
5. Accurate interpretation of investigation results	Chest X-ray Abnormal blood results indicating heart attack Heart attack on 3-lead ECG and 12-lead ECG	Chest X-ray normal All blood results interpreted correctly **20.46.09** 3-lead ECG findings noted **27.24.29** 12-lead ECG findings discussed, and correct diagnosis reached	
6. Determine a working diagnosis	Heart attack	**33.22.55** Heart attack	
7. Call for appropriate advice	Medical emergency team call Cardiology doctor	**21.01.00** Medical emergency team call **20.45.62** Decide to call cardiologist/cardiac catheter lab **43.56.80** Updates cardiology doctor	
8. Prioritise and manage immediate Loop 2 findings if appropriate	Appropriate drugs After call to registrar – Heparin	**15.08.09** Blood oxygen saturation has dropped so oxygen commenced **15.52.18** Organises pain relief and anti-vomiting drugs (for back pain) **21.18.93** Suggesting appropriate heart attack management – drugs **23.35.77** Drugs administered **37.03.62** Oxygen turned down	37.03.62 Prompted by coach. This is really important in heart attack to not have high-flow oxygen running

		41.53.39 Pain relief medication administered	
9. Complete unfinished Loop 1 components	Palpate radial pulses Check capillary refill Check urine output Performs 3-lead ECG Intravenous cannulation Examine the abdomen	**17.25.79** 3-lead ECG suggested **19.28.89** 3-lead ECG applied ECG noticed at **20.33.34** **33.40.07** Intravenous cannulation	Abdominal exam should have been part of E in Loop 1 then considered again in case of aortic bleeding
10. Recycle through relevant Loop 1 components	Recycle approx. 5 minutely especially heart rate Blood pressure Blood oxygen saturation 3-lead ECG	**15.17.45** Blood oxygen level falls – oxygen applied via nasal prongs **19.25.42** Change oxygen mask **25.50.15** Recycle through some Loop 1 components **28.35.15** Rechecks BP BP rechecked for first time since 08.58.20 **37.41.52** Rechecks BP **40.03.41** Rechecks BP	
11. Management challenges identified	Possibly drug doses and administration	**17.39.62** Pain relief dose not known **22.35.59** Drug doses not known	Coach assisted with all drug routes, frequency, and doses

Note.

BP = Blood pressure

Ddx = Differential diagnoses

E = Exposure

ECG = Electrocardiogram

In contrast to Loop 1 management guidelines, steps in the Loop 2 framework were well known to the students from prior learning in the first year of their course when the explicit process of clinical reasoning was taught. As with Loop 1 processes, experienced clinicians undertake some Loop 2 steps in parallel rather than sequentially. Novices, however, require more structure in order to gather all the relevant information and to ensure that essential patient data is not missed.

Process and Progression

Over and above knowing the crucial steps listed in the Loop 2 framework, analysis of the data has identified a number of common challenges faced by each group in relation to the *process* of completing Loop 2. These can be further broken down into three main categories, explained in detail as follows:

1. Overlapping of Loop 1 and Loop 2 activities
2. Diagnostic reasoning
3. Developing a management plan.

1. Overlapping of Loop 1 and Loop 2 activities

(a) Appropriate prioritisation of Loop 2 over Loop 1. In the early simulations, movement from Loop 1 to Loop 2 often occurred prematurely as students started to think about a diagnosis without completing sufficient Loop 1 steps to stabilise the patient. The risk with that is deranged physiology, such as low blood pressure, is then not rectified in a timely manner. It was the responsibility of the coach to ensure that this did not happen (Group 2, Sim 5, 15.26.53). Over time, it became evident that groups could decide when enough Loop 1 steps had been completed *for the time being* to ensure patient stability and which steps could wait until later, with Loop 2 steps being addressed in the meantime. An example of this is commencing empirical antibiotics in the setting of severe infection (sepsis), which is a time-critical and life-saving step, prior to completion of all of the Loop 1 steps (Group 3, Sim 6, 08.12.65). Two issues are of interest here. First, students were able to prioritise their actions accordingly, and second, the increased cognitive capacity available to them from both the automatisation of Loop 1 steps and the increased sophistication of reasoning skills resulted in more expert problem-solving.

(b) Continued recycling of relevant Loop 1 steps. As previously discussed in this chapter, recycling through relevant Loop 1 steps was often prompted by a particular action, rather than becoming a routine component of management. Recycling became a more automated action in the later simulations, especially once students had made a diagnosis and commenced a management plan. It was as though there was a 'break in the traffic' at that time and the idea of recycling then occurred to them (Group 3, Sim 6, 34.52.28).

2. Diagnostic reasoning

(a) The diagnostic reasoning process, supported by the coach, followed a basic novice approach of data acquisition, problem representation, and hypotheses generation and refinement (McColl, 2008), followed by the development of a management plan.

As expected at novice level, in the early simulation students used a lengthy process of small reasoning steps based on detailed, biomedical concepts.

Example:

Edward (in the setting of an unconscious patient with a low respiratory rate): '... constricted pupils, hang on, if you take away your sympathetic ... has she got a fractured rib affecting the vagus – and slowed her breathing and a flail chest ... if her ICP is up, then her pupils would constrict'. (Group 2, Sim 4, 22.54.89)

In this example, Edward is trying to figure out why the patient would have constricted pupils and a low respiratory rate (a classic presentation of a narcotic drug overdose) based on basic bioscience knowledge rather than on experience with clinical presentations, which he doesn't yet have. He is searching for cues in a disorganised manner. Novices are often unfamiliar with the salience and diagnosticity of cues compared to experts who have learned the value of certain indicators (Kluge, 2014). Diagnosticity is the value of certain indicators in comparison to others.

In this next example, based on the same diagnosis, Cindy's previous exposure to a similar case enables her to use pattern recognition in making her diagnosis:

> *Cindy (on examining an unconscious patient with a low respiratory rate): 'How much morphine has she had? [40 mg], ok let's check her pupils … they're constricted, ok so she's had an overdose, lets reverse that'.* (Mixed group, Pop-up 1, 06.26.35)

Students needed to actively search through their networks to generate a list of symptoms that might confirm their diagnosis, as demonstrated in this example:

> *Akshay (describing a patient with volume overload): 'she's got bilateral crackles, she has new onset peripheral oedema, an elevated JPV, she has high blood pressure and is tachycardic, and low urine output'.* (Group 3, Sim 3, 32.27.38)

As reasoning skills developed, direct lines of reasoning between concepts within a particular network became evident:

> *James (in discussion with the rest of the group): '… we don't have any localising signs … has she been coughing? … so, if we're thinking that we've got some peritonism … and distension … we're thinking fluid leak, haemorrhage … that would account for the hypotension … anastomosis might have leaked …'.* (Group 1, Sim 5, 16.41.48)

In this example, James is demonstrating reasoning through an encapsulated network evidenced by his direct linking of patient findings and clinical concepts in forming a differential diagnosis.

(b) Relevant investigations linked to differential diagnoses. In the early simulations, students were having difficulty combining data collection and evaluation into their reasoning. Twenty-two per cent (22.9%) of Loop 2 coaching interactions were related to investigations such as blood tests and X-rays. Occasionally, groups were unaware of a specific investigation in relation to the differential diagnosis. More commonly, students were not thinking broadly enough about their list of differential diagnoses when they ordered investigations based only on the most likely diagnosis. The problem with that is if the investigation results do not confirm the most likely diagnosis, then they have to start over. Investigations are required to both rule in and rule out likely diagnoses. This is typical of novice learners who tend to collect as much information as possible based on one diagnosis, whereas experts adapt their data collection to verify or falsify their list of differential diagnoses (Boshuizen & Schmidt, 2008).

Examples of coach-initiated investigations:

Coach to group: 'The way to think about your investigations is to link your list to your differentials, so causes of AF [irregular heart rhythm]?' (Group 3, Sim 5, 17.39.38)

Coach to group: 'Think about this list here (of differentials) ... anything else (to investigate)?' (Group 1, Sim 3, 31.07.97)

Examples of student-initiated investigations as reasoning expertise developed:

Johnny (in relation to causes of AF): 'We've done an ECG, we should get a chest X-ray, ... let's think bloods here ... infection, old lady, big surgery, hypovolaemia ... FBE ... UEC, CRP, ESR, ... definitely a gas – she's hypoxic ... troponin and a D dimer's not gunna help, she'll be clotting everywhere'. (Group 1, Sim 6, 37.18.84)

In this example, Johnny listed the causes of atrial fibrillation and aligned relevant investigations to them including recognition of the one that would not add value.

Akshay: 'We need to get two sets of cultures, FBE looking for infection ... a UEC looking for electrolyte imbalances that might be causing the delirium ... probably *should take something like thyroid function tests given that this might be a different cause of delirium … um, extended electrolytes, CRP… are there any other bloods we want to do? [Group discussion]. We'll do a urinalysis, we'll do a chest X-ray … a VBG and not an ABG looking for lactate and electrolytes as her sat is ok'.* (Group 3, Sim 6, 13.41.02)

In this example, Akshay listed the investigations required to confirm sepsis and to also verify the likely cause of the sepsis. At the same time, he was mindful that there could be another cause of the patient's delirium besides sepsis and ordered investigations to rule those out.

(c) Awareness of bias. One of the immediate goals of Loop 2 is the use of clinical reasoning skills to formulate differential diagnoses. From there, and considering further information such as investigation results, a working diagnosis is made (the most likely of the two or three differential diagnoses). An important role for the coach was to promote discussion around possible differential diagnoses to prevent premature closure, which is when a diagnostic conclusion is arrived at too early in the diagnostic process. Fifteen per cent (15%) of Loop 2 coaching episodes were directed at this goal, with the majority of those being in the early simulations.

Early simulation examples:

Coach to team leader: 'So you've said STEMI [heart attack]. Johnny, do you have any other differentials?'
Johnny: 'um, could be a respiratory cause, afebrile, could be exacerbation of GORD … PE are we thinking? …' (Group 1, Sim 1, 29.39.06)

Coach to group: 'You've got sepsis up here … any other things this could be?
Rose: 'PE presenting with fever and sinus tachycardia'. (Discussion ensues)
Daniel: 'internal bleeding …'
Alan: 'Can we rule out anaphylaxis?' (Discussion ensues) (Group 2, Sim 2, 35.57.48)

In both these examples, the groups had initially made the correct diagnosis but the coach prompted a conversation in order for them to consider other possibilities through modelling expert reflective thinking such as, 'Is there anything else going on here? Have I missed anything?'

The following examples show that in later simulations, groups were doing this unprompted:

> *Akshay (summarising a delirious septic patient): 'we'll also get a thyroid function test in case there's another reason for delirium …'*
> *Guy: 'Can we rule out a PE?' (Discussion ensues)*
> *Akshay: 'The other thing we mustn't forget is cerebral pathology'.* (Group 3, Sim 5, 15.01.79)

3. Developing a management plan

(a) Developing a management plan within their scope of practice. The majority of the Loop 2 coaching (40%) was spent on matters relating to the management of a particular diagnosis and in particular to the practice limitations for junior doctors (which is what these students are role-playing) in executing that plan. Groups who articulated management mnemonics appeared to have a more structured approach to case management than those who did not. Mnemonics are language tools for retention that can make complex cases become more straightforward through the simplification of large amounts of information.

Examples:

> *Johnny (team leader): '… we can think about the dose of the morphine going in, we've got oxygen going on, what else … nitrates and aspirin'.*
> *Coach: 'So you're using MONA?'*
> *Johnny: 'MONA, yeah'*
> *James and Kane: 'yeah, yeah'.* (Group 1, Sim 1, 21.21.00)

In this example, the team used the mnemonic MONA (morphine, oxygen, nitrates, and antiplatelets) to guide their management of a heart attack. In this case, the coach then went on to teach an extension to MONA known as MONASH where the S and the H stand for two further management strategies that are not available to junior doctors but are steps that they need to be aware of in order to consult a more senior clinician to authorise.

In contrast, Group 2 did not have a structured approach to managing a heart attack as they had not been previously taught the MONA mnemonic:

Coach: 'What can we do about this?'
Alan: 'Put him on more oxygen?'
Honey: 'Relieve pain'
Alan: 'Give GTN. I wouldn't give opioids … it might mask the pain'.
Coach: 'Let's look at a way of approaching this'. (Explains MONA) (Group 2, Sim 1, 39.47.10)

In this example where the students were unaware of the MONA mnemonic, they were planning to increase the oxygen (contraindicated in heart attack), were reluctant to give morphine (which is indicated) and had overlooked arguably the most important treatment step by failing to administer aspirin. This is an example of how a language tool such as a mnemonic can assist in managing large amounts of information in a more straightforward way.

(b) Prioritisation of management issues. In many cases that junior doctors are called to, the situation is one of a 'diagnosis within a diagnosis'. For example, a patient might have developed fluid on the lungs (acute pulmonary oedema) that requires diagnosing and urgent management. However, acute pulmonary oedema does not just happen – it is caused by an underlying problem such as heart failure, which also requires addressing. The priorities in such a case are to treat the symptoms – in this case, the acute pulmonary oedema – and investigate the cause afterwards. Another example of this 'treat first, find the cause later' situation is sepsis where the timely administration of antibiotics takes priority over determining the focus of the infection. This interim step of first treating the symptoms is not something medical students are accustomed to. Their previous learning has been based on making the eventual, underlying diagnosis. Because of that, in many simulations they were distracted by the eventual diagnosis, which they were prioritising over the presenting diagnosis.

Examples:

Alan (team leader): 'What do you think is happening here guys?' *Edward: 'She's in heart failure, but I'm not sure why, whether it's infection …'* *Alan: 'Are we not worried about PE anymore?'* *Rose: 'That's still a possibility, but isn't it appropriate to just diurese her and get the fluid out of her?'* *Alan: 'Well, let's just send a eGFR and see how her kidneys are and creatinine are and if that's ok we'll give her some frusemide, … got her on oxygen … and we'll give her some digoxin and some beta blockers'* (Group 2, Sim 6, 29.13.00)

In this example of acute pulmonary oedema, Alan and Edward are concerned about the underlying cause of possible heart failure due to infection or pulmonary embolus (lung clot). Rose has prioritised correctly and wants to diurese the patient (administer fluid medication) to remove excess fluid. Alan wants to wait, check kidneys, and treat heart failure in the meantime. The coach intervened and confirmed Rose's plan. As it turned out, in this case the acute pulmonary oedema had not been caused by heart failure and there was no need to treat the patient with the drugs that Alan had suggested.

It is interesting to note that there were two cases that all three groups found the most challenging to manage and that required major interruptions by the coach. One was acute pulmonary oedema and the other was an acute onset atrial fibrillation (heart rhythm abnormality). For both of these diagnoses, students had learnt about and had seen patients with these conditions, but only in their chronic forms. In other words, the concept of acute pulmonary oedema being caused by something other than heart failure and atrial fibrillation having acute precipitants was unfamiliar to them and necessitated new learning.

Not surprisingly, and somewhat linked to scope of practice matters (the limitations surrounding what a junior doctor can and cannot do), issues around medications were challenging for students to deal with. In nearly every case, they knew what medication was required, but were unfamiliar with doses and frequency. This did not change over time as each case required different medications. Although important, this was not a major concern for two reasons. First, medication options are changing constantly based on new evidence, and by the time these students become junior doctors, this may have happened. Second, an important lesson for students during the simulations was to learn how to access supporting information such as hospital guidelines and protocols, iPhone apps, and electronic data sources that will guide their prescribing habits in future practice. These sources were discussed and utilised in each simulation.

More coaching time was spent in Loop 2 for Groups 1 and 3. As Loop 1 steps became more automated, less coaching was required. This is expected and is an important step in the gradual release of responsibility by the coach. In Loop 1, the content was initially unfamiliar, but it remained consistent over time and with repeated practice it became more familiar and automatised. In contrast, Loop 2 content was familiar, having been learnt elsewhere, but the detail changed depending on the particular diagnosis, which increased the need for coaching episodes targeted to the specifics of the case. For all groups, Loop 2 coaching episodes decreased over time. Group 2 struggled for several simulations without appointing a team leader, as discussed later in this chapter. For this reason, they required more Loop 1 coaching to support successful completion of that loop. They were then able to make minor process adjustment, such as altering the order of Loop 1 steps to suit the situation, and eventually progressed to a competent level, evidenced by a more automated approach to Loop 1 routines merging with Loop 2 priorities.

Effective teamwork is required to ensure that taskwork is coordinated and completed. A model of teamwork emerging from the data is discussed in the next section.

3.2.2 Teamwork

As a result of inductive data coding and analysis, there are seven distinct teamwork activities that were deemed essential for successful performance in the simulations, all of which combined to facilitate a coordinated performance. The following progression increases in complexity, ranging from the appointment of a leader through to sophisticated strategies that can only be undertaken in the presence of that leader. In other words, if a leader is not appointed, the other outcomes are difficult to achieve.

1. A leader is explicitly appointed and maintains leader position and role for the duration of the case.
2. There is an initial allocation of Loop 1 primary followed by secondary roles to address patient assessment and stabilisation.

3. Patient status is regularly updated.
4. The patient management plan is discussed and negotiated.
5. Loop 2 roles are appropriately prioritised and allocated.
6. There are recurring '5 for 5' patient status updates.
7. A cycle of intervention and review continues until the management plan is implemented.

Each section of the progression will be defined and supported by illustrative examples. The following extracts from the analysis of the video recordings show effective and ineffective examples of leadership and teamwork.

1. A leader is explicitly appointed and maintains a leadership role and position for the duration of the case. By remaining in position, at the foot of the bed, the leader does not focus on taskwork and maintains *situation awareness* for the duration of the simulation. The other team members are aware of who the leader is and what their own role is. The team leader is responsible for the facilitation of goal clarification and achievement, and actively seeks out the opinions and ideas of other team members.
a. Effective team leadership There are two critical factors for effective and efficient leadership appointment. A team leader must be explicitly appointed by mutual agreement or offers to lead the team, and the leader must be willing to lead the team. Example: *Johnny (to the entire group): 'I'm going to team lead'.* (Group 1, Sim 1, 05.37.74) Johnny remained at the foot of the bed for the duration of the case. He maintained *situation awareness*, which is evidenced by his ability to notice oversights by team members and was not tempted out of position, as demonstrated in the example below: *Johnny: 'Can we get that ECG [heart monitor] going?'* (Group 1, Sim 6,

23.49.67)

Johnny (to Daniel): 'Dan, analyse that [pointing to ECG] – I can't see it from here'. (Group 1, Sim 6, 29.09.15)

b. Ineffective team leadership

There were two types of ineffective leadership observed.

i. A team leader is appointed but does not adhere to the role nor maintain position. He/she appears to be unaware of the role requirements and becomes distracted with performing taskwork and loses *situation awareness*. The team members are unable to report back their findings and team structure is lost.

Example:

Kane (team leader; to James): 'Can you do a history …?

James: 'Oh you start, you do the first bit …' (Group 1, Sim 3, 06.01.85)

Kane commenced history taking causing him to leave his leadership position, which he did not return to for the duration of the case. He continued with taskwork and did not have a sense of where the rest of the team were up to as he had lost his *situation awareness:*

Kane (while examining the patient's eyes as part of disability): 'How are we going with the airways, breathing?' (Group 1, Sim 3, 11.12.34)

At this point, the team had moved on from airway and breathing, but no one had reported their findings back to Kane. There was no response to Kane's question from the group as they were focused on individual tasks.

Of particular note here was the team's ability, in the absence of a leader, to self-allocate roles and effectively complete Loop 1.

ii. A team leader is not appointed, and the entire group tackle various components of each step resulting in components being omitted or doubled up on. Steps are incomplete and out of order. Vital information is not communicated, and decisions are not made.

Example:

Edward: 'Hi James [patient], my name is Edward, can you hear me?'
(Long pause)
Daniel: 'How are you feeling at the moment James?' (patient responds)
Rose: 'What do you mean?' (patient responds)
Daniel: 'Do you have any pain anywhere, James?' (patient responds)
Daniel: 'Whereabouts ... do you have any pain in your chest, James?' (patient responds)
Rose: 'You seem like you're breathing a little fast. Are you short of breath?'
Alan: 'Let's check his vitals'. (Group 2, Sim 1, 14.23.95)

A lack of leadership has resulted in unstructured history taking without assessment. The team appear to be searching for a diagnosis (heart attack or heart failure) without first stabilising the patient. One team member (Alan) tried on several occasions to lead the team in a 'hint-and-hope' style by prompting, 'can we check his vitals?' (15.29.37)/'Are we happy with his sats?' (16.41.84)/'Should we give him oxygen?' (25.36.90), without actually doing any of it himself. It appeared he had emerged as a 'hands off' leader, but because he had not been explicitly elected as leader, the team members seemed unaware of his suggestions. As a result, his status remained one of team member and his prompts went unnoticed.

2.There is an initial allocation of Loop 1 primary followed by secondary roles to address patient assessment and stabilisation.

The leader allocates Loop 1 primary roles (usually DRSABC). The leader ensures that all components of each step are completed and that team members stay in their roles. Loop 1 secondary roles (usually DEFG) are then assigned once the primary tasks have been completed. Each primary task takes different amounts of time, so secondary roles are allocated sequentially as team members become available. Often, the allocation of these roles is dependent on team members using their initiative when they find themselves available for an extra task.

a. Effective role allocation

The team leader allocates roles in their entirety and the instructions are clear and succinct. For example, the role of managing the steps of airway and breathing is assigned and not the individual components of those steps. The team members are aware of the components of each step and are capable of completing them. Separating the roles into primary and secondary tasks ensures appropriate *task loading.*

Example:

> *Johnny (team leader): 'Can I get James to go and take a brief history? Lauren, you're on airways, Kane, breathing and circulation, um, Lauren, you're on airways and breathing, Kane, circulation'.* (Group 1, Sim 1, 05.41.60)

The team members simultaneously commenced their assigned tasks.

In this example, Johnny used team members' names to explicitly allocate roles. He demonstrated adaptive capacity by self-correcting when he realised that airway and breathing together is a more logical combination than breathing and circulation together. He allocated roles based on steps rather than components of steps, demonstrating a mutual trust in his team members that they were capable of completing entire steps.

Secondary role allocation:

> *James (team leader) to Declan: You've done breathing now?'*
> *Declan: 'Yeah'.*
> *James: 'Do you want to do disability?' (hands Declan a torch)*
> *Declan: 'Sure'.* (Group 1, Sim 4, 19.03.88)

In this example, James has ensured that sequentially interdependent tasks have been completed prior to allocating secondary tasks thereby preventing *task overload*.

b. Ineffective role allocation

There were two types of ineffective role allocation observed.

i. The team leader allocates individual components of each step sequentially to team members. For example, rather than allocating breathing, component tasks such as respiratory rate or blood oxygen saturation are allocated to different team members. This results in random information being reported back to the team leader, potentially out of sequence. This is an inefficient use of resources and causes a delay in all of the relevant findings being conveyed to the team leader. Additionally, the team leader then needs to synthesise that information rather than the team member doing so prior to reporting back.

Example:

Cindy (team leader): So, Rob, do you want to say hi to Fred [patient], see how he's getting on?'
Rob: 'How are you feeling Fred?'
Cindy: 'Akshay, do you want to check airway?'
Akshay: 'Open up your mouth, Fred ... he's cyanosed'.
Cindy: 'OK ... Akshay, just take resps essentially'.
Cindy: 'So he's an AVPU of V'. (Group 3, Sim 1, 03.38.60)

Everyone watches Akshay count the respirations. Circulation is not assessed simultaneously, and oxygen is not applied as part of the fix-as-you-go rule.

In this example, the leader breaks down the components into steps and allocates them one at a time. The rest of the team stand around the patient watching, which results in an inefficient and segmented approach.

Sally (team leader): Can you take her vitals and do a general inspection?'
Edward: 'Who?'
Sally: 'General inspection'.
Edward: 'Just everyone?'
Sally: 'Yeah'.

Daniel: 'What's her breathing and circulation?'

Rose: 'Will I do airway?'

Edward: 'I'll just pull this [the bedclothes] back'. (Group 2, Sim 2, 10.51.42)

In this example, primary and secondary roles are confused with vague instructions from the leader, and the team is unsure about roles and priorities. Edward pulls the bedclothes back to do exposure before any primary tasks are completed.

ii. A team leader is not appointed resulting in a lack of role allocation.

Example:

Alan: 'Let's check his vitals'.

Edward: 'The respiratory rate is high'.

Coach: 'What is it Edward?'

Edward: 'Oh, I haven't counted it'.

Alan (to coach): 'Do you have a torch?'

Rose: 'Let's check the BP'.

Daniel (to patient): 'How does your breathing feel, James?' (third time it has been asked)

Coach: 'Has anyone listened to his chest?'

(Three team members listen to the chest) (Group 3, Sim 1, 15.29.85)

In this example, individual components are being randomly addressed. The torch is used to check pupils (D), which should be done after A, B, and C. There is no harm in doing it sooner, but there are other more important assessments to be made first especially in a patient who is responding appropriately to questions. The group was unable to prioritise without the direction of a leader.

Sally (all to patient): 'Can you squeeze my hand, James?'

Rose: 'Can you wiggle your toes?'

Alan: 'Can you push down for me?'

Sally: 'Pull up?' (Group 2, Sim 1, 20.05.58)

In this example, three team members are all doing components of the same examination (D) rather than it being allocated to one person.

3. Patient status is regularly updated.

The status of the patient is periodically updated to the entire team by the team leader. With each team member focused on his or her individual tasks and reporting information back to the leader, it is unlikely that the whole team is aware of the overall patient status. This update also allows for contributions from team members about ongoing priorities and management decisions. The major prerequisite for successful teamwork is the development of a *shared mental model* among all team members. One technique for this team orientation process is the 5 for 5 timeout, which metaphorically means taking 5 seconds to quickly assess the situation and to then plan the next 5 minutes to prioritise action alternatives. It provides a concrete basis for a decision point. It is usually called by the team leader but can be initiated by a team member who may feel out of touch with what is happening. It is an opportunity to *share mental models* of the situation and plan a *shared team schema* going forward.

a. Effective patient status update

A 5 for 5 is called at key times such as at the completion of the primary roles, at the completion of the secondary roles, when new information comes to light, or there is a change in patient status.

Example:

Minnie (team leader): 'Let's do a 5 for 5, so … airway?'
Cindy: 'Ok'.
Minnie: 'How is her breathing?'
Akshay: 'Lung bases are clear bilaterally'.
Cindy: 'She's a little bit short of breath'.
Rob: 'Her respiratory rate?'
Cindy: 'We don't know her respiratory rate'.

Minnie: 'So no wheeze or anything?'

Rob: '93% on room air'.

Minnie: 'And how is her BP?'

Rob: 'She's hypotensive'. (Group 3, Sim 4, 22.57.38)

In this example, Minnie calls a 5 for 5 in order for the team to report back their findings to her. Overlooked components are identified and clinical picture is emerging.

Lauren (team leader): 'Can we take a 5 for 5? ... everyone quickly pause. We've got a 73-year-old man ... [case summary] ... his BP is ok, but he's tachycardic ... thoughts?'

Johnny: 'Um, are *we happy with the blood pressure?'*

Kane: 'What's his normal blood pressure?' (145/90)

Lauren: 'Ok, so it's low then, so we're thinking ... so this is in line with sepsis?'

Johnny: 'Sepsis'.

Lauren: 'Yep'. (Group 1, Sim 2, 15.11.90)

In this example, Johnny's contribution to the discussion led to Lauren realising the blood pressure was low and that others in the team were not happy with it. Alerting her to this gave Lauren *control knowledge* of the situation. This in turn led to a differential diagnosis of sepsis, which Lauren may have overlooked had she not been alerted to the patient's normal blood pressure. This is an example of team cognition where input from several team members resulted in improved decision-making.

James (team member): 'Can we do a 5 for 5?

Johnny (team member): 'A 5 for 5, I reckon'.

James (to Kane, team leader): 'You can run it'.

Johnny: 'Just to see where we are at'. (Group 1, Sim 3, 14.29.94)

In this example, Kane, the team leader, had left his leadership position and had lost *situation awareness*. The team appeared to be aware of this and requested a 5 for 5 to get an update on where they were at and direct Kane back to his leadership role. This is an example of how effective teams develop *backup behaviours* for coming to the

aid of other team members in time of need.
b. Ineffective patient status update Team members discuss findings and make decisions independently resulting in a lack of team structure and the *non-sharing of mental models*. *Edward counts the respiratory rate (four breaths per minute), but does not declare it.* *Daniel: 'Let's do an inspection'. (exposure)* *Coach: 'Let's stick with B for now … we have a respiratory rate of four'.* *Sally (team leader): 'A respiratory rate of four???'* *Edward: 'Four'.* *Coach: 'And we're hypoxic'.* *Edward: 'That's not good'.* (Group 3, Sim 4, 15.57.77) In this example, team members are not reporting back vital information to the team leader in a structured format. The coach needed to focus the group's attention back to B and later reminded them of an earlier complementary finding in order for them to appreciate the situation. Had a 5 for 5 been called, Sally may have received all the information held by team members and been able to prioritise what to do next.

4. The patient management plan is discussed and negotiated. There is evidence of *team cognition* to adapt decisions and tasks to meet the needs of the patient and to synchronise team activities. This is a type of *situation monitoring* activity that often takes place during transition phases such as from initial assessment to patient stabilisation.
a. Effective patient management plan discussion and negotiation This can occur during a formal 5 for 5 but also at other opportune times when decisions need to be made. Open dialogue makes it easy for team members to share mental models and arrive at mutually agreed decisions.

Example:

Kane (team leader): 'You put a cannula in, Declan'.

Declan: 'Yeah, sure'.

Kane: 'And put a line in for fluids'.

Declan: 'Normal saline?'

Kane: 'Yeah, does anyone have any other suggestions?

James: 'I think a moderate fluid challenge'. (Group 1, Sim 3, 20.02.56)

In this example, the team leader requests a cannula and Declan checks back regarding the type of fluid. The leader then asks for other suggestions, which both confirm his decision and give the team an opportunity to offer other ideas.

Johnny (team leader): 'So, 2, 3, aVF, is that what we're thinking?'

Declan: '2,3 ... it sounds anterior'.

Johnny: 'Inferior'.

Kane: 'Inferior'.

Declan: 'Well. that would explain the nausea'.

Johnny: 'So we think ... right coronary artery?'

Declan: '2, 3, aVF is consistent with inferior ...'.

Johnny: 'So, right coronary blockage'. (Group 1, Sim 1, 33.51.34)

In this example, an accurate diagnosis was made based on a group discussion. After an initial suggestion that the location of the heart attack was anterior, other group members corrected this to inferior. Johnny's collegial leadership approach to the conversation – 'Is that what we're thinking'/'So we think …' – invites input from other team members.

b. Ineffective patient management plan discussion and negotiation

There is no discussion between the team members regarding patient management options and decisions. Patient interventions such as administering oxygen are decided by individual team members. Management actions are not prioritised. Different mental models result in conflict if team members fail to communicate appropriately.

Example:

Rose (to coach): 'Does she have signs of peritonitis?'

Coach: 'Yes'.

Rose: 'So we need to call the surgeon?'

Alan: 'What are her respirations?'

Daniel: 'Do you want to give her surgical team a call – let them know what's going on'.

Rose (to coach): 'Should we have we done everything before we call them …?'

Sally: '… do cultures'

Rose: 'Stabilise her first?'

Daniel: 'Her results won't come back for a while. Something has gone wrong'.

Coach: 'What has that resulted in?'

Sally: 'Septic shock'.

Coach: 'So one of you needs to be getting a cannula in, giving fluids, taking bloods while another makes the call …' (Group 2, Sim 5, 14.51.97)

In this example, all suggestions are directed at the coach rather than the team discussing the options among themselves. The coach was responsible for all of the decisions and the group was unable to prioritise patient stabilisation requirements.

5. **Loop 2 tasks are appropriately prioritised and allocated.**

   Loop 2 tasks are allocated either at the completion of Loop 1 or during Loop 1 tasks if appropriate. During Loop 2, however, Loop 1 findings must also be regularly reviewed in order to reassess and update patient status. As expertise develops and Loop 1 tasks become automated, Loop 2 tasks are simultaneously introduced earlier in the case.

a. Effective allocation of Loop 2 tasks

Unlike Loop 1 tasks, Loop 2 tasks are less well structured. Although they follow a typical format, the detail changes according to the situation, so more attention needs to be placed on the specifics of the case. Tasks are allocated by the team leader, often during the 5 for 5 phase, through discussion and negotiation.

Example:

> *Lauren (team leader): 'I reckon we need to get some bloods as soon as we can and then start empiric antibiotics'.*
>
> *James: 'Do we need an overall assessment?'*
>
> *Johnny: 'Have we done a complete cycle?*
>
> *Lauren 'No, I thought we'd get half the team onto that and half onto starting some bloods'*
>
> *Kane: 'And should we get a glucose as well?'*
>
> *Team response: 'Yes, yep, yeah'*
>
> *Lauren: 'Ok, can I get Kane, can I get you on exposure, can I get ...?'*
>
> *Johnny: '... drawing up?'*
>
> *Lauren: 'Are you happy to be that person?'*
>
> *Johnny: 'Yep'.*
>
> *Lauren: 'Yes, ok, can you get a line in?'* (Group 1, Sim 2, 16.48.50)

In this example, the team recognised the need for empiric antibiotics (a life-saving treatment) to treat sepsis before they had completed Loop 1. Lauren split her team into two in order to simultaneously achieve all Loop1 and Loop 2 goals.

> *James (team leader): 'So, IM adrenaline and then access, bloods, tell me when you've got it in, then we'll reassess and get the fluids in ... so while you're preparing the adrenaline, you're getting access and you can maintain the airway and check his conscious state'.* (Group 1, Sim 4, 27.06.22)

In this example, James's planning prioritises and allocates Loop 2 tasks to specific team members and also readdresses Loop 1 issues requiring attention. Use of closed-loop communication – 'tell me when you've got it in' – ensures awareness of task completion.

b. Ineffective allocation of Loop 2 roles

It is almost impossible for Loop 2 roles to be assigned if a leader has not been appointed. There is no team structure, no shared mental models, and no capacity to prioritise.

Example:

Coach: 'Do you want to allocate some roles?'

Daniel: 'Rose was going to …'.

Alan: 'Did you want to … or do you want me to do it?'

Edward: 'Rose will you do morphine?'

Coach: 'Edward, you sound like the leader, what would you like Alan to do?'

Edward: 'You can do aspirin'.

Coach: 'What would you like Sally to do?'

Edward: '12-lead ECG'.

Coach: 'What would you like Daniel to do?'

Edward: 'Nitrates'. (Group 3, Sim 1, 51.19.88)

In this example, a team leader had not been appointed so it was up to the coach to appoint one by stealth during the case, as no one was able to delegate roles.

6. There are recurring 5 for 5 patient status updates.

Regular 5 for 5 team communication episodes are utilised to regularly update the team for continued sharing of *mental models* and *team schema accuracy.*

a. Effective 5 for 5 updates

The team leader, or team members, update the team at critical times during the case, in particular as new information comes to light, the patient status changes, or the team has updated information to contribute to the discussion.

Example:

Akshay (team leader): 'Ok, 5 for 5. So, are we all happy where we are at the moment? All pay attention please. We're treating this lady with presumed *urosepsis with empiric cephtriaxone, which we're preparing now. Is there anything else anyone feels like we should be doing?'*

Rob: 'So, other thoughts about infection, look at the chest …'

Guy: 'So, we've sent blood cultures, we're getting a chest X-ray, I mean, have we done a catheter culture?'

Akshay: 'Yep, there are signs of infection'.

Rob: 'Clinically, elsewhere doesn't seem likely, to find any other …'

Akshay: '… alright, we'll get that cephtriaxone in'.

Minnie: 'Are we concerned about her kidney function as well?'

Akshay: 'Well, we're waiting on bloods to come back'.

Akshay: 'Alright, Guy?'

Guy: 'Do you want me to ring up?'

Akshay: 'Minnie do you want to write up the results?' (Group 7, Sim 6, 34.47.40)

In this example, Akshay updates the team and opens up the discussion for the team to contribute to ongoing planning. Guy's question about a catheter culture is an example of how team members, focused on their tasks, are unaware of what has occurred in the meantime. Minnie's question about renal function (which is important to know prior to administering antibiotics) prompts a call for blood results. Minnie, writing the results on the board, gives the whole team a chance to view them.

James (team leader): 'Do we want to do a quick 5 for 5 for what we've got?'

Lauren (setting up an IV): 'Do you want me to keep going?'

James: 'No, maybe pause'.

(Johnny gives a clinical update)

James: 'Ok, so a quick list of differentials – what we're worried about – so, the most likely cause of the shock?'

Declan: 'Anaphylaxis …'

James: 'Anaphylaxis'.

Declan: '… would tie all of those together'.

James: 'I'm happy with that … then second would be … we can't rule out sepsis … we've got a rash, we've got a temperature of 38.4, so we need to be mindful of that'.

James: '... so IM adrenaline and then access, bloods, tell me when you've got it in, then we'll reassess and get the fluids in'. (Group 1, Sim 4, 22.39.72)

In this example, the working diagnosis of anaphylaxis is confirmed through group consensus. James closes the communication loop with 'tell me when you've got it in' and plans to follow up with a further reassessment.

In both of these examples the team leader asks for everyone's attention – 'all pay attention please', 'no, maybe pause' – so that the entire team is focused on the discussion and not distracted by other tasks that would need their attention at that time.

Alan (team leader): 5 for 5. Tell me what you're doing. Daniel – airway – tell me what's happening with his airway'.

Daniel: 'Um, she's breathing. I'm not sure of the respiratory rate at this exact moment but she's not responding to the increased oxygen we're giving her, unfortunately'.

Alan: Right, breathing and circulation'.

Sally: 'So, in terms of elevated JVP, there's a third heart sound, no murmurs ... and, um, in terms of breathing, elevated respiratory rate and respiratory effort increased and, um, course crackles and pitting oedema as well'.

Alan: 'Right, so we've taken a sample of her blood?'

Rose: 'Yes, I've sent it'.

Alan: 'So, what do you think is happening you guys?'

Sally: 'She's in heart failure'.

Edward: 'Heart failure – don't know exactly why – whether it's an infection or whether she's got a pulmonary embolus'.

Alan: 'Are we not worried about PE anymore?'

Edward: 'I'm a bit worried about it'.

Rose: 'That's still a possibility, so is it appropriate to diurese her to get fluid out?' (Group 3, Sim 6, 29.12.42)

In this example, rather than summing up himself, the team leader got each team member to comment on the tasks they were assigned in order to gather all available information. Rather than offering a diagnosis, he asked the team for their opinions, which is an effective way to check that nothing is being overlooked. There was a risk here that the discussion would focus on the cause rather than on the management of the problem until Rose asked whether or not it was appropriate to diurese. This refocused the group back onto the management of the problem.

b. Ineffective 5 for 5 patient status updates

5 for 5, or any other team communication strategy, is not utilised to update the team resulting in confusion and a lack of direction in the patient management plan.

Sally (team leader): 'Have we sent off the bloods?'
(No response)
Daniel: 'What are the bloods for?'
Sally: 'She's breathing at six per minute'.
Sally: 'What's the blood pressure?'
(Coach shows Sally the low glucometer reading of 1.4)
Sally: 'She has a glucose of 1.4'.
The team are focused on their tasks and don't take any notice of this significant finding.
Sally: 'SHE HAS A GLUCOSE OF 1.4!'
Team member: 'That's fine'.
Edward: 'No it's not'.
Sally: 'Severely hypoglycaemic'.
Rose: 'Do we give her glucose?'
Daniel: 'Oh wow!' (Group 3, Sim 4, 28.34.24)

In this example, random questions are being asked to no one in particular and a response is not forthcoming. Important findings are at risk of being overlooked.

7. A cycle of intervention and review continues until the management plan is implemented.

During Loop 2 activities, the patient remains at risk of becoming unstable. In parallel to the constant review of Loop 2 activities, Loop 1 monitoring must be ongoing.

a. Effective cycling of intervention and review

Timely reassessment may be directed by the team leader based on patient status, or one team member might be tasked with ongoing reassessment for the duration of the case. The patient status is updated to the leader by the team member. This may be in an abbreviated form such as 'breathing is fine/unchanged', rather than a complete rundown of all components of breathing.

Example:

> *Lauren (team leader): 'So with regards to what we need to do next, we need ... access, so we'll get Johnny on that, we need investigations, and we need to think about causes, so we'll start another cycle of ABCD, but while you're doing that also make sure you're checking lines and things and sites for infection'.* (Group 1, Sim 5, 08.07.81)

In this example Lauren doesn't actually specify who does what and leaves it up to the team to work it out. They all went back to their original primary tasks and completed ABCD again. Returning to original tasks is an example of effective patient monitoring. For example, if the original team member who listens to a patient's chest remains in that role, they are more likely to pick up any changes to subsequent chest sounds than someone who is listening for the first time.

> *Akshay (team leader): 'Can we do another blood pressure while we're at it?'*
> *Akshay: 'Rob, can you screen the pupils again please?'*
> *Akshay (to patient): 'Sheryl, would you be able to wiggle your feet for me?'*
> *Akshay: 'And check the blood pressure now'.*
> *Cindy: 'Um, one hundred'.*
> *Akshay: That's actually gone up. Heart rate is 106'.* (Group 7, Sim 6, 31.33.97)

In this example, Akshay specifies which components of ABCD he wants rechecked and allocates those tasks.

b. Ineffective cycling of intervention and review

Example:

Rose: 'What else can we do?'

Edward: 'Where are we up to ... we're at D, aren't we?'

Sally (team leader): 'Yes, I'll get you to do that'.

Rose: 'Check eyes'.

Sally: 'Edward, how's his airway?'

Edward: 'Good, I think'.

Sally: 'Eyes still pinpoint'. (Group 2, Sim 4, 32.05.45)

In this example, the team are trying to figure out what they need to do next. The team leader also seems unsure and asks unstructured and isolated questions.

The degree to which groups engaged in effective teamwork influenced three main phases of each simulation:

1. Efficiently completing the required steps and their associated actions (data collection)
2. Working out what was going on (differential diagnoses)
3. Planning how best to manage the situation (development of a management plan).

Completing the required steps was achieved when a designated team leader allocated roles and received feedback as tasks were completed. Working out what was going on required formal opportunities for group communication that enabled team problem-solving. Planning management strategies depended on the sharing of *team mental models* in order to coordinate and prioritise management goals.

For Groups 1 and 3, effective leadership teamwork strategies continued to improve over the course of the six simulations. One explanation for this is that students had started to develop/build a schema around what effective leadership looked like by observing effective leadership in previous simulations and were developing what Rentsch and Hall (1994) describe as *team member schema similarity* whereby team members, through their interactions, form impressions of each other that affect team functioning (Fiore &

Salas, 2009). From a situated learning perspective, Lave (1988) hypothesises that observation assists learners to develop a conceptual model of the task or role prior to attempting to perform it. Given this context, it is not surprising that students were now independently developing new skills based on their role in previous simulations resulting in the group now forming varying, rather than homogenous, degrees of skill.

Despite all three groups experiencing two introductory simulations where team leadership was proposed as an important component of group coordination, failure to appoint a team leader had a detrimental effect on Group 2. In particular, they failed to reach a 'synergistic threshold' (the collective effort achieving more than the sum of individual efforts) due to process losses (Zaccaro, Heinen, & Shuffler, 2012, p. 83). Process losses refer to 'inefficient problem-solving in groups due to an inability to combine their individual capabilities or an unwillingness of team members to exert adequate levels of individual effort' (Zaccaro et al., 2012, p. 83). Effective team leadership is required to focus on directing collective group action in order to reach and maintain a state of minimal process loss.

As with other coaching episodes, teamwork coaching decreased after simulation number four across all teams as team members became more experienced working with each other in complex and dynamic situations. Teamwork capabilities developed through observation of others, through opportunities to practise new tasks in a variety of roles, and through coaching support. Coaching, in all its forms, is discussed in the next chapter.

Effective team leadership created conditions that enabled teams to complete the iterative cycles of assessment, stabilisation, diagnosis, and management of the patient in a timely and efficient manner. In particular, leadership traits such as maintaining situation awareness, sharing mental models and team member schema similarity, and encouraging team cognition resulted in a coordinated, systematic, and a well-thought-out approach to achieving satisfactory case completion. In contrast, when a team leader was not appointed, some taskwork actions were independently achieved, but there was an overall lack of teamwork behaviours resulting in a disorganised and inefficient performance that potentially delayed patient stabilisation.

3.3 Transfer of learning: Pop-up simulations

Three unscheduled pop-up simulations were conducted at the completion of the second-year program to provide opportunities for students to transfer previously learnt skills to new situations, albeit within simulation. In these pop-ups, students had an opportunity to participate in spur-of-the-moment simulations with students from other groups designed to vary the context in which they practised. These simulations were designed to depict the randomness of real-life incidents that junior doctors are exposed to when they are called to the bedside and need to function in unfamiliar teams. Although primarily an extra learning opportunity for students, the pop-ups were also intended to be a test of what learning the students had retained and were able to apply spontaneously as required in the case. Teamwork behaviours were of particular interest due to the transient nature of team formation in these simulations.

In the scheduled second-year simulations, the learning objectives are primarily *near* transfer. That is, students applying new knowledge and skills in a consistent way in a familiar environment such as Loop 1 steps. The objective of pop-up simulations was to assess *far* transfer where previous learning is evidenced in different work contexts and skills are adapted to new situations (Clark et al., 2006). In this case, the different context remained within simulation, as medical students do not treat patients in the real world, and thus the focus was on working in different teams during an unexpected event. The coach played a more hybrid coach-/nurse-type role in order to more closely replicate the real world and to also provide coaching support if required. The pop-up simulations therefore differed from the scheduled second-year simulations in the following ways:

- Students from various groups were randomly approached while focused on other activities and were therefore unable to plan their approach to the situation beforehand.
- The simulation cases were not linked to a related clinical placement. Students would need to *think back* to previous learning to put the case into context.
- There was a lack of familiarity within the team.
- The coach played a less visible role as a hybrid coach/nurse to offer support if required while still being able to later measure for retention without too much influence.

3.3.1 Taskwork

Analysis of the video recordings using the Loop 1 taskwork framework (see Appendix E as an example) indicates that taskwork schema was recalled and applied in all three pop-up simulations either spontaneously by team members or because of direction from the team leader. Team leadership, discussed in the next section, was the crucial feature in the efficiency of taskwork completion. There was early merging of Loop 1 and Loop 2 steps in each of the three cases. In the first case, strong leadership from Cindy ensured all Loop 1 steps were completed; however, she needed to explicitly direct her team to complete every step. In other words, the team was not proactive and required guidance from her. The two team members were original Group 2 members who relied strongly on the coach for guidance in their previous scheduled simulations. Cindy appeared to be aware of the eventual diagnosis after the initial handover from the nurse, and then again at the 4-minute and 5-minute marks, but she does not state it. She finally declares the diagnosis at 6 minutes.

In the second pop-up, within two minutes of receiving the patient handover, a team member suggested antibiotics but did not direct the communication to the team leader, and, as a result, it went unheard and was therefore not acted upon. After 5 minutes, the team leader summed up the case, a diagnosis was made, and antibiotics were then successfully suggested again.

In Pop-up 3, strong leadership from Johnny saw Loop 1 completed within three minutes. A diagnosis was made in under eight minutes (see Appendix G for an example).

3.3.2 Teamwork

Three contrasting leadership styles were apparent, all of which directly affected teamwork. First, in Pop-up 1, Cindy immediately assumed a leadership role through positioning herself at the foot of the patient's bed and allocating roles. There was not any prior discussion or declaration of leadership. One of her team members, Edward, did not appear to understand what a circulation assessment entailed, so Cindy listed off the components of that step in order of priority. Edward worked backwards from that list, which resulted in the most important finding, the blood pressure, being assessed last. Both of Cindy's team members were coincidentally from Group 2 and had struggled all year with leadership and teamwork issues. It appeared that they were both happy to be instructed in what to do and did not demonstrate any synthesis of clinical findings or contribution to group cognition. Perhaps for that reason, Cindy did not share her diagnostic mental model with the group through a formal 5 for 5 or an informal discussion. Subsequently, the diagnosis was not declared until quite late, despite Cindy appearing to have realised what it was much earlier. It appeared that the teamwork schema Cindy had developed within her own team was unique to that team and she was unable to transfer those skills to a different team.

In Pop-up 2, Simon was elected team leader. He immediately took up a leadership position but did not allocate roles. The team automatically started the patient assessment, but without being allocated specific roles, some steps were completed twice by different team members, and important findings, such a slow oxygen saturation, were overlooked for a period of time. Team members split into two smaller teams with each having independent conversations about antibiotics, although no one explicitly stated that they thought the diagnosis was sepsis. It appeared that they all assumed that the others knew what they were thinking, so there was no sharing of mental models. Through specific patient questioning, Simon was obviously considering a diagnosis of pulmonary embolus, but again this wasn't made explicit and therefore not discussed with other team members. This group took the longest to complete Loop 1 and to state their diagnosis.

In Pop-up 3, Johnny was elected team leader prior to entering the simulation room. His strong leadership was demonstrated through remaining in a leadership role and position for the duration of the case, specifically allocating roles, using team members' names, using closed-loop communication strategies, sharing mental models, and calling 5 for 5 group discussions. This group was the fastest to complete Loop 1 and to state their diagnosis. Johnny had developed core teamwork schema from previously participating in a group with superior teamwork behaviours and he was then able to generalise those skills to a different team.

According to Custers and Boshuizen (2002), transfer is more likely to occur when well-developed schema is automatically applied to a new situation, such as in this case. For transfer to occur, skills need to be appropriately adapted through adherence to sound principles (Fish & Higgs, 2008). Activation of pre-existing relevant knowledge was evidenced by the groups' ability to successfully complete a random simulation that they were unprepared for. Transfer of learning, albeit within simulation, was especially noticeable from the perspective of taskwork where schema was recalled and applied by individual group members. Less noteworthy was the transference of teamwork skills, which varied between groups and was determined by the quality of leadership behaviours.

3.4 Retention of learning: Fourth year simulations

The fourth-year simulations were designed to more closely replicate the clinical conditions in which the students will find themselves the following year as junior doctors. As a result, the simulations were more time pressured and dynamic. As outlined in the literature review, cognitive apprenticeship theory, with its added dimensions of increasing complexity and diversity of simulated cases, coupled with the withdrawal of scaffolding by the coach, ensured that the simulations were sequenced over the entire medical curriculum. This offered students opportunities to adapt their problem-solving skills to a range of differing situations. Increased complexity was achieved in the following ways:

1. Difficulty in discriminating between patient cues. For example, straightforward patient management did not have the expected outcome.
2. Increased interdependence between the variables. For example, one action may have multiple immediate consequences.
3. Time pressure is increased requiring attentional resources. For example, the problem changed during the decision-making process.
4. The number of simultaneous taskwork requirements is increased.

The simulations therefore differed from second-year in the following ways:

- An individual student, rather than the entire group, would first enter the simulation room at the request of a nurse to assess a clinically deteriorating patient for a particular reason.
- If the student required more help, either two more students from the same group could be called, or a MET could be activated, or both.
- A useful and reasonable nurse was present in the room as a team member, but a coach was not present.

- The patient was more unstable and the situation more dynamic and time critical than in second year.
- The simulation was played out in real time and generally lasted for about 15 minutes.
- There were only two simulations with one half of the group participating in the first simulation and the other half participating in the second simulation. As there were four or five team members, some students participated in both simulations.
- Students not participating in the simulation observed in real time in a remote location via a live audio-visual feed for the purposes of contributing to the later debriefing exercise.
- There was an immediate post-hoc debriefing to address issues arising from the simulation in which all students – both participants and observers – were able to contribute.
- The order of the simulations differed according to the timetable, so Groups 1 and 3 participated in simulation A first and Group 2 undertook simulation B first.

Specific action progressions, which prioritised ideal Loop 1 and Loop 2 steps, were developed for each of the two cases. A form of cognitive task analysis was again utilised to identify the knowledge, skills, and information processing aspects that underlie expected performance. These progressions were verified by an expert medical clinician. As discussed earlier in this chapter, as expertise develops, clinicians are able to apply more sophisticated reasoning strategies enabling them to move seamlessly between Loops 1 and 2 based on patient priorities. The following progression (Table 19) is an example of simulation A, designed as a Loop 1 and Loop 2 hybrid model of desired student actions. Expected progression through the case, described in column 2 of the table, has been developed from careful selection of case-specific priorities from the original and complete Loop 1 and Loop 2 taskwork and teamwork skills frameworks. It is important to note here that the nature of the fourth-year simulations was a focus on Loop 1 clinical deterioration management with less emphasis on clinical reasoning. In both cases, the cause of the deterioration was of less significance than the management; however, differential diagnoses did need attention and a management plan was required. As such, data analysis of retention is predominantly based on Loop 1 attributes. Unlike clinical deterioration, clinical reasoning skills are both taught and assessed in other settings, so it is reasonable to emphasise Loop 1 results in this section.

Fourth-year cases typically ran in the following way with the case being introduced to the students as:

> *Mrs Jones is a 65-year-old lady who is three hours post-thyroidectomy [a neck operation] who is having trouble breathing. Can you please review her?*

The student would usually undertake a basic assessment of the patient and then call for help as the patient's condition deteriorated. One or two other students would then enter the room and receive a handover regarding the patient and assist in her care. A MET call would also ideally be made. The nurse played a supportive but not proactive role, assisting with clinical tasks but not contributing to decision-making. As stated, a post-hoc debriefing followed to discuss the case and explore clinical decision-making.

Simulations

Simulation A was a case of a 62-year-old lady who had returned from the operating theatre 3 hours earlier after having her thyroid gland removed from her neck. Some postoperative deep wound swelling was putting pressure on her airway and causing airway obstruction and breathing difficulties.

Table 19. Fourth-year taskwork progression chart: Simulation A: thyroid case

1. Loop	2. Expected progression through case	3. Findings	Teamwork considerations
Loop 1	Introduces self and takes a brief targeted history	Patient states, 'I can't breathe'	Takes a leadership role
	Check response	Patient is alert and speaking in single words only	Recognise urgency of situation
	Request monitoring of vital signs	Fast respiratory rate Low blood oxygen level Fast heart rate Slightly elevated blood pressure	Utilise nursing staff appropriately through requests for assistance

	Commence high-flow oxygen	Has no effect Consider escalating oxygen therapy	
	Call for help	MET call Local assistance Surgeon	Retain or hand over leadership as appropriate Provide relevant and succinct handover to incoming help Prioritise and allocate tasks appropriately Share mental model(s) Team members report back findings
	Commence Loop 1 cycle Check airway by looking in mouth Check for airway noises	No lip or tongue swelling No foreign body Upper airway obstruction noise (stridor) present	
	Examine surgical site	Front of neck is swollen around surgical site	
	Auscultate chest	Check for normal air entry	
	Prioritise fixing A and B Alert surgical team	Remove all neck stitches immediately Patient requires urgent anaesthetic and surgical support	Check with nursing staff if unsure Allocate tasks to most appropriate person Communicate with appropriate personnel and convey urgency of situation
	Reassess A and B	Slight improvement	Call 5 for 5 as

		only	appropriate
	Continue to cycle through CDEFG	With blood pressure stable, this is not a priority but should be completed if there are enough resources. IV cannula when time permits	Allocate tasks depending on situation and resources
Loop 2	Consider other diagnoses as airway obstruction has not resolved: anaphylaxis aspiration nerve damage in surgery Check patient's past history and allergies	Removal of stitches does not immediately relieve airway obstruction Need to rule out other causes	Discuss other causes with team
	Recycle regularly through RABC	Oxygen saturation remains low but stable	Regularly update patient status
	Reassure and explain proceedings to patient at regular intervals	Explain situation	

Note.

ABCDEFG = Airway, breathing, circulation, disability, exposure, (don't ever) forget glucose

MET = Medical Emergency Team

Retention of learning was again analysed through efficiency of taskwork and effectiveness of teamwork. Rather than time stamping each individual action in the simulations, as was done to analyse second-year learning, significant essential actions and events deemed necessary for successful case completion were identified and are analysed in the following section. These could only be completed if Loop 1 principles were applied and relevant clinical findings were appropriately interpreted.

Simulations

Case A

Case A was a postoperative thyroidectomy upper airway obstruction due to surgical swelling. This requires urgent attention, with the priorities being calling for help and removing the neck sutures while supporting the breathing with high-flow oxygen. Calling for surgical advice is also imperative, although it is expected that the sutures would be removed by the junior doctor without prior surgical approval. The swelling does not immediately resolve, so students need to consider other diagnoses; in particular, they need to consider anaphylaxis by examining the airway, auscultating the chest, looking for a rash, and ruling out a trigger. The fact that the blood pressure remained high was reassuring in this case and means that if it was anaphylaxis the patient was still stable from a circulation perspective. Table 20 maps the progression of each group through the case.

Table 20. Fourth-year taskwork progression chart: Thyroid case

Case: Postoperative neck swelling causing airway obstruction (after thyroid surgery)				
Critical actions – Time taken from commencement of simulation				
	Group 1, Sim 1	**Group 2, Sim 2**	**Group 3, Sim 1**	**Mean**
Recognises urgency of situation	Immediate	Immediate	Immediate	Immediate
High-flow oxygen	0.14 min	1.73 min	0.34 min	0.70 min
Call for help	2.1 min	0.16 min	0.34 min	0.75 min
Removal of stitches	5.35 min	4.97 min	3.07 min	4.46 min
Call to surgeon	4.51 min	5.73 min	7.04 min	5.76 min
Effective prioritisation	IV cannula prioritised over removal of sutures	Adrenaline prioritised over removal of stitches but overruled by another team member	Leader unsure what to prioritise and checks with nurse	
Complete Loop 1 cycle	Suggested but not done	Incomplete	Done	

Consider other causes	Anaphylaxis DVT Intraoperative nerve damage	Anaphylaxis	Not done

Note.

Min = minutes

DVT = Deep vein thrombosis

IV = Intravenous

Postoperative neck swelling is a rare but life-threatening emergency. All teams recognised the urgency of the situation and the need to remove the neck sutures. Prioritising calling for help, supporting the breathing with high-flow oxygen, and removal of the stitches all happened quickly, which was ideal. Despite knowing that the stitches needed to be removed, not all teams realised that it was actually their job to do so and needed prompting or reassurance from the nurse, which is how it could play out in a real situation. This is another example of students' learning about scope of practice issues, including what is expected of a junior doctor in this situation. Loop 1 completion did not always occur. It could be argued that it was unnecessary to check D (disability) in this situation, but exposure definitely needed to be completed in order to rule out anaphylaxis as a differential diagnosis when the airway remained compromised.

By adhering to the prescriptive nature of the Loop 1 cycle, Group 3 completed the cycle once they had addressed higher priority tasks. Although they didn't consider other differential diagnoses, had they found an abnormality while completing the cycle, such as a rash, then another diagnosis such as anaphylaxis may have been considered. This supports the use of the Loop 1 cycle and in particular its completion, as important findings are then not overlooked and can become a trigger for further clinical reasoning. Group 2 did not complete the Loop 1 cycle despite this being their second simulation (they had already participated in the other simulation directly beforehand). Group 1 suggested several times that they complete Loop 1 but did not do it. No one was specifically allocated that task by the leader.

Teamwork attributes listed in Table 21, deemed necessary for successful coordination and completion of the cases, were constructed as a result of the analysis of the critical actions identified during the second-year simulations and were also used in fourth year to assess student achievement levels in teamwork.

Table 21. Fourth-year teamwork action chart: Thyroid case

Critical actions	Group 1	Group 2	Group 3
Leader appointed	Johnny is first in the room and subsequently checked with incoming team if they wanted him to remain leader. Leader left the leadership position to remove stitches, which should have been allocated to someone else.	Rose is first in the room and remains team leader, although she does get distracted at times by doing taskwork.	Rob is first in the room and assumes a leadership role. He does not leave the leadership position or get distracted with taskwork.
Succinct handover to incoming team	'She has significant swelling around the neck. She needs to be opened up and decompressed'.	'She's having difficulty breathing so she's quite tachycardic with a low saturation'.	'I think she's got a partially obstructed airway'.
Roles allocated	Yes	Yes	Yes
Patient status updates	No specific 5 for 5 but several interactive group discussions.	Yes. One specific 5 for 5 and other interactive team discussions.	No specific 5 for 5 but several interactive group discussions and good closed-loop communication within the team.
Secondary roles allocated	No	Yes	Yes
Patient management plan negotiated	Yes	Yes	Yes
Ongoing patient review	A, B, and C checked regularly. Analgesia discussed.	Yes	Cycle completed and regularly rechecked. Analgesia discussed.

Note. ABC = Airway, breathing, circulation

Effective teamwork attributes were evident most of the time with strong leadership and communication. In particular, the handover statements made by the leaders to the incoming team were succinct and relevant. Early in this simulation, when there were many competing priorities, the smaller size of the team (compared to second year) resulted in two of the team leaders losing situation awareness. They both became distracted with taskwork issues that they identified needing completing but did not have the resources to do so. In both cases, the priorities could have been managed differently. For example, Group 1 prioritised an intravenous cannula over removing the stitches. This was probably due to their misunderstanding that they required approval from a more senior surgical clinician prior to doing so. Similarly, a formal 5 for 5 was only undertaken on one occasion and this again may have been due to the ease with which a smaller team can communicate less formally, which happened frequently.

Case B

Case B was a large postoperative haematemesis (vomiting blood) following knee replacement surgery on a background of long-term anti-inflammatory medication use and blood thinning medication for new atrial fibrillation. This requires urgent attention, with the priorities being to call for help and volume resuscitating the patient with intravenous fluid using two large bore intravenous cannulas while administering high-flow oxygen. While cannulating, students need to take several blood tests to assess how much blood has been lost and to organise a blood transfusion. It is also imperative to call for surgical and haematological advice to guide their management plan. The following table maps the progression of each group through the case.

Table 22. Fourth-year taskwork progression chart: Haematemesis case

Case: Postoperative haematemesis **Critical actions – Time taken from commencement of simulation**				
	Group 1, Sim 1	**Group 2, Sim 2**	**Group 3, Sim 1**	**Mean**
Recognises urgency of situation	Not immediate – does call for help but they then require a prompt from the nurse	Immediate	Immediate	
Calls for help	1.14 min	1.11 min	0.75 min	1.33 min
High-flow oxygen	2.04 min	1.78 min	1.82 min	1.88 min
Intravenous	2.13	1.78 min	0.82 min	1.57 min

cannulation (including blood investigations) and volume resuscitation	Kane asks the nurse to cannulate, which is an excellent use of resources			
Effective prioritisation	After 5 minutes, although they are concerned about the blood loss, they are trying to figure out the cause instead of fixing the immediate problem	Yes	Yes	
Call to Gastroenterology	6.76 min	4.06 min	5.65 min	5.49 min
Call to Haematology	15.07 min	10.93 min	8.58 min	11.52 min
Complete Loop 1 cycle	Yes	No – stopped at C	Yes	
Regularly recycles through Loop 1	No	Sporadic	Yes	

Note. min= minutes

Team leaders in Groups 2 and 3 responded appropriately to the situation and immediately recognised that they needed help. Kane in Group 1 seemed less concerned, and it required two prompts from the nurse about how unwell the patient looked for him to call for help. When he did, it was local help only (his two colleagues) and not a MET call, which was required. His two colleagues were surprised to later find out that a MET call had not been made prior to their arrival into the room. Nonetheless, all groups appropriately prioritised the basic steps required to stabilise the patient with A, B, and C being efficiently assessed and addressed. At one stage, Group 1 were at risk of losing focus when they became distracted by working out the cause of the bleeding rather than fixing it first and required a prompt from the nurse to get them back on track. All groups realised they needed specialised assistance to deal with the problem, and some were unsure exactly who to call so they utilised the experience of the nurse to find out.

Despite the blood pressure being the primary concern in this patient, only Group 3 checked it more than twice during the case.

Table 23. Fourth-year teamwork action chart: Haematemesis case

Critical actions	Group 1	Group 2	Group 3
Leader appointed	Kane enters room first and remains in a leadership role.	Ali enters room first and remains in a leadership role.	Akshay enters the room first and remains in a leadership role. He states to the team that he will lead.
Succinct handover to incoming team	'She's just vomited a litre and a half of blood and she's recently had AF'.	'She's a knee replacement who has had a massive haematemesis'.	Carol's a knee replacement who's had three episodes of massive haematemesis, so I'm quite concerned'.
Roles allocated	Yes. Kane also effectively utilises the nurse to IV cannulate in order to free up his team.	Yes. Rose reports back to Alan that IV cannulas are in and what would he like her to do now.	Yes
Patient status updates	Yes	Yes	Yes. Good use of closed-loop communication evident. Formal 5 for 5 called.
Secondary roles allocated	Yes	Yes	Yes
Patient management plan negotiated	Yes, although they became fixated on the cause at one point and the nurse prompted them to prioritise the volume resuscitation.	Yes.	Yes. Akshay asks the team if there is anything else they should be doing.
Ongoing patient review	Yes	Yes	Yes

Note. IV = intravenous

Effective leadership attributes were demonstrated by each leader with all of them remaining in the leadership role for the duration of the case and not becoming distracted with taskwork. As in Case A, the handover to the incoming team was succinct and relevant. Effective followership was evidenced through closed-loop communication, as was effective completion of allocated tasks with associated feedback and sharing of mental models. As with Case A, a formal 5 for 5 was only called on one occasion, but all groups made use of opportunities for timeout-type discussions for ongoing patient management planning and revision.

The fourth-year simulations also required interaction with other team members, such as the nurse. All groups made effective use of the nurse's knowledge and experience by allocating technical tasks to her and asking her advice on protocol-based procedures. In particular, Kane in Group 1 made excellent use of the nurse's skills in asking her to cannulate the patient. This freed up his medical team members to complete more medically focused tasks. This is more in line with interprofessional, team-based practice and adds an extra dimension to their 'preview' of real-world aspects of patient management.

Key to the successful management of these two simulated cases was the ability of students to quickly retrieve and appropriately apply previously developed clinical schema. Data analysis of fourth-year simulations provides important evidence of how students were able to effectively and efficiently organise themselves to achieve these goals. As might be anticipated, students displayed reliance on learnt frameworks that they were able to adapt to suit the demands of the situation. Learning from previous experience in simulation, coupled with observational learning in the workplace is evident from both their performances in the simulations and their reflexive discussions in the focus group interviews. It does not appear than there has been any significant degree of skill attrition since the completion of second-year simulations.

When considered in the context of the Dreyfus and Dreyfus (1980) model of skills acquisition, the data suggest that students have progressed from novice to competent/proficient in their simulated clinical practice. They are no longer rigidly adhering to the explicit rules of Loop 1 and Loop 2 in a process-driven way but are able to prioritise and manage important aspects of the case and plan their action in relation to the specific management goal they are trying to achieve. This is more in line with the performance of experienced clinicians in METs and RRTs described earlier in this chapter. It is even more impressive when one considers the increased complexities associated with the fourth-year simulations and the long retention interval between simulation programs. It appears that simulation provides an authentic pathway for the development of expertise in patient management otherwise unavailable to medical students during their training.

3.5 Summary

This chapter has summarised the data findings and analysis from the perspective of learning, transfer, and retention of patient management teamwork and taskwork skills. Learning frameworks were developed to map the application of skills and provided a platform for data analysis. Two educational design research interventions, introduced to improve both the content and the delivery of second-year simulations, provided the conditions under which the data were collected. Data analyses were approached from two perspectives, the learning process and the learning progression, thus addressing the main research question. Chapter 4 will address the coaching and cognitive support required to support learning. Student reflections on learning are also included in this chapter.

Chapter 4: Findings – Coaching and student reflections

4.1 Introduction

This chapter examines the data relating to the cognitive support required for students to achieve successful completion of simulated scenarios and overall skill progression. This includes the role of the coach and use of cognitive aids to support learning. The chapter also summarises the themes emerging from focus group interviews held at the completion of second year and fourth year.

From a teaching perspective, facilitation of the simulations was undertaken by an in-game coach, as described in section 1.8.2. This is a complex, multifaceted role undertaken by an expert clinician simulationist. The coaching role is crucial in supporting and providing immediate feedback to assist in progression through the case. Analysis of this new role identifies the type and frequency of coaching episodes required to support learning, the impact those episodes have on student actions, and how these change over time. Other dimensions arising from the data, such as the opinions of the students themselves gleaned through the focus group interviews, are used to augment the findings.

4.2 Coaching

For the purposes of this study, coaching is defined as the learning support that students required to progress through the case while both staying in flow and managing extraneous cognitive load. At times, extra information was given to students by the coach, but rather than supporting learning, it was patient-related information that the mannequin or the technology could not provide. An example of this would be the students requesting the neck vein measurement or asking if the patient felt warm or cool to touch – features the mannequin cannot simulate. Other information again not related to coaching but provided by the coach included details from the patient's medical record such as the vital signs observation chart.

In this study, coaching episodes were only coded in relation to the *thinking* required to manage the case and not to the actual *doing* that supported the case, so coaching related to psychomotor skills, such as intravenous cannulation, were not coded. Although important, the teaching and learning of psychomotor skills are not the focus of this study. As discussed in section 1.9.1, coaching techniques were based on the cognitive apprenticeship model and are focused on higher order metacognitive skills and problem-solving/task completion.

As represented in Table 24, three different categories of six cognitive apprenticeship coaching techniques were applied in the simulations. The first three techniques – modelling, monitoring, and scaffolding – described in Table 24 and colour-coded blue represent *proactive* coaching and are activated in response to student *inaction*. In other words, the coach identified a situation where coaching was required in order for students to progress through the case. These episodes were supportive in nature and were designed to help students gain an integrated set of skills through processes of guided practice. The second two techniques colour-coded yellow represent *reactive* coaching – articulation and answering/confirming – which were in response to student *action* and provided opportunities for students to both demonstrate their own problem-solving strategies and have factual questions answered, thus allowing them to progress through the case. These were less supportive in nature from the perspective of progression and formed part of the interactive dialogue between students and coach through the students' agency to initiate an interaction with the coach. Third, in pink, and not a component of Brown et al.'s (1989) cognitive apprenticeship coaching taxonomy, is *major interruption* as a standalone category whereby the coach needs to pause the simulation in order to provide explicit guidelines or approaches to the current situation that would otherwise prevent the students' progression through the case. Despite a pause in the simulation being contrary to the theoretical basis of the in-game coach role, on some occasions the lack of students' theoretical understanding of the situation meant they were unable to progress through the case without a didactic component being introduced to the simulation. One further technique traditionally found in the cognitive apprenticeship coaching taxonomy, that of reflection, will be discussed later in Loop 3 findings from focus group interviews.

Table 24. Coaching based on cognitive apprenticeship (adapted from Brown et al., 1989)

Coaching technique	Acuity	Definition	Category	Example
Modelling	Proactive	Modelling a task (including a problem) Giving an example of working through a problem	Coach identifies a need	Coach: 'The way I think about it is …'
Monitoring	Proactive	Giving feedback and hints Giving reminders about overlooked or unnoticed events	Coach identifies a need	Coach: 'Don't forget the oxygen that you mentioned earlier'.
Scaffolding	Proactive	Helping with some aspects of the case Making suggestions Using physical supports	Coach identifies a need	Coach: 'Why don't we do a Wells score anyway and document it in the notes' Presence of whiteboard and poster in the room
Articulation	Reactive	Students have an opportunity to articulate their knowledge, reasoning, or problem-solving processes	Coach checking	Coach: 'What is your fluid plan?' Coach: 'What is your approach to managing X?'
Answering/ confirming	Reactive	Responding to their specific questions	Coach affirming	Student: 'What dose of drug X should I give?' Student: 'I think 1 gram is the correct dose'/Coach: 'Yes, that's correct'.
Major interruption	Interruption	An intervention requires the coach's leadership to direct the activity and focus the group on a particular approach to patient management	Major teaching intervention identified	Coach: 'I think we should stop for a minute and discuss an approach to x'.

4.2.1 Coaching episodes

(For the purpose of this study, coaching interventions are referred to as coaching *episodes* so as not to confuse the reader with the *research interventions*.)

Coaching episodes had the following three broad aims:

- To provide conditions conducive to learning that set students up for successful completion of the simulation.
- To offer mental routines that students can internalise and systematise through repeated practice
- To generate discussion that students were unlikely to engage in spontaneously through 'think-aloud' prompts.

The following data represent the number and types of coaching episodes applied in the simulations. In the first table for each group, coaching methods are listed in the first column. Across the top of the table are the six simulations. Cells are populated with the number of coaching episodes related to categories L1 (Loop 1), L2 (Loop 2), and T (Teamwork). Totals for both coaching types and for each category are in the final column and row.

4.2.1.1 Group 1

Table 25. Group 1 coaching episodes

	Sim 1			Sim 2			Sim 3			Sim 4			Sim 5			Sim 6			Total
	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	
Modelling					1									2					3
Monitoring	2	2	1	1	2		1	1			1		2	1			1		15
Scaffolding				1	3			5	2	2	4	1	1	2			1		22
Articulation	1	3		1	3		2	3		2	2			6					23
Answering	1			2	1		1	1			1			3					10
Interrupting								1											1
Totals	4	5	1	5	10		4	11	2	4	8	1	3	14			2		74

Note: Sim = simulation

For Group 1, Loop 1 coaching episodes remained fairly constant across all simulations, decreasing to nil in their final simulation. Loop 2 episodes were low in the first simulation where the focus was mainly on completing all of the steps in both loops rather than sophisticated clinical reasoning. As expertise developed and Loop 1 became more automated, coaching episodes focused more on Loop 2, with the specifics of each case requiring differing levels of support. There was a peak in Loop 2 coaching in simulation five where there were several instances of the team working independently. As a result, the coach explored their thinking through articulation strategies to ensure they were on the correct pathway. Teamwork was a strong feature of this group who demonstrated early the teamwork practices learnt from the introductory simulations. On one occasion, simulation three, where leadership was weak, the team still managed to complete all of the tasks in a self-directed way and drew the leader back into the leadership role through their request from him for a 5 for 5. There were several instances when this group explicitly applied skills learnt in previous simulations.

The following pie charts (Figure 26) represent total percentages of coaching episodes. The first chart, 'Coaching Activity', breaks down coaching into Loop 1, Loop 2, and teamwork. The second chart further breaks down the overall nature of coaching into proactive, reactive, and major interruption categories. Finally, in order to specifically define the more consequential coaching episodes, proactive coaching is further broken down into Loop 1, Loop 2, and teamwork. The reason for this third breakdown is that it provides added meaning through more accurate representation of coaching episodes that were significant in terms of enabling student progression through the case, such as providing direction or prompting actions. In comparison, reactive coaching was often more generalised in nature and not specifically related to progression, such as students stating their list of priorities, which did not require coaching guidance. Also, as expertise developed, coaching adjustments were made to accommodate the increased experience of the learner. For example, clinically sophisticated reactive coaching conversations in the later simulations would not have been appropriate earlier in the simulation curriculum. As such, they were not required for satisfactory case completion but occurred spontaneously as a by-product of the situation. Such coaching examples artificially inflated the overall coaching episodes.

Almost three quarters of all coaching episodes were in Loop 2. This is probably due to the high element interactivity in Loop 2 (Clark et al., 2006). In Loop 2, several knowledge elements need to be coordinated to achieve the goal. For example, the investigation findings need to be considered in association with the patient findings. By comparison, Loop 1 has low element interactivity in that it is approached in a serial rather than a coordinated manner, as evidenced by the fix-as-you-go rule.

In Group 1, approximately half of all coaching was proactive, and the other half was reactive, with one major interruption for this group that occurred in simulation three when a formalised approach to the diagnosis was required from the coach. Within proactive coaching, in the region of three quarters was in Loop 2.

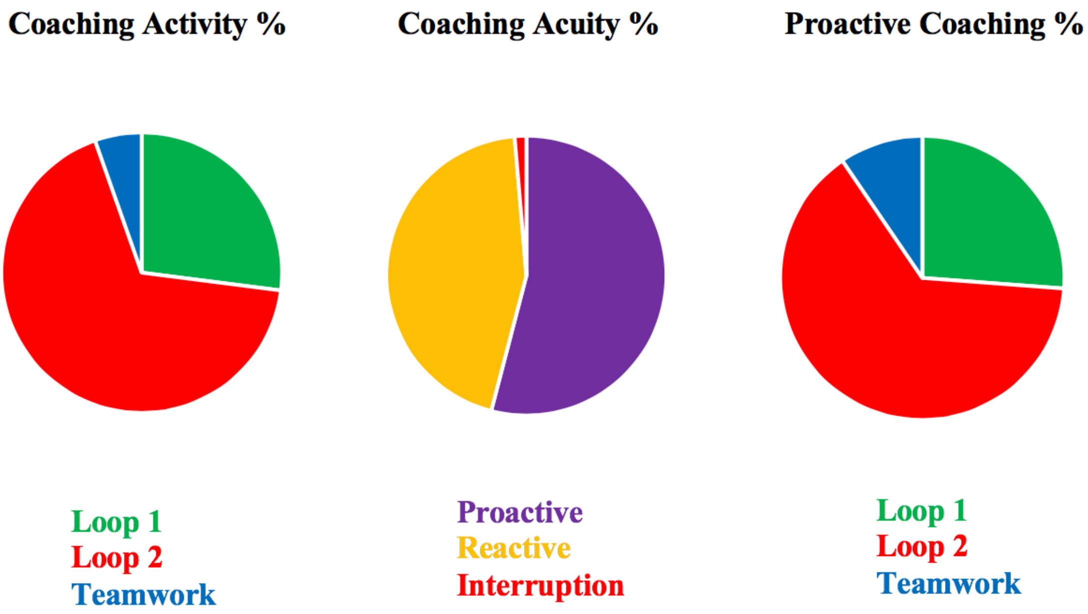

Figure 26. Group 1 coaching data percentages.

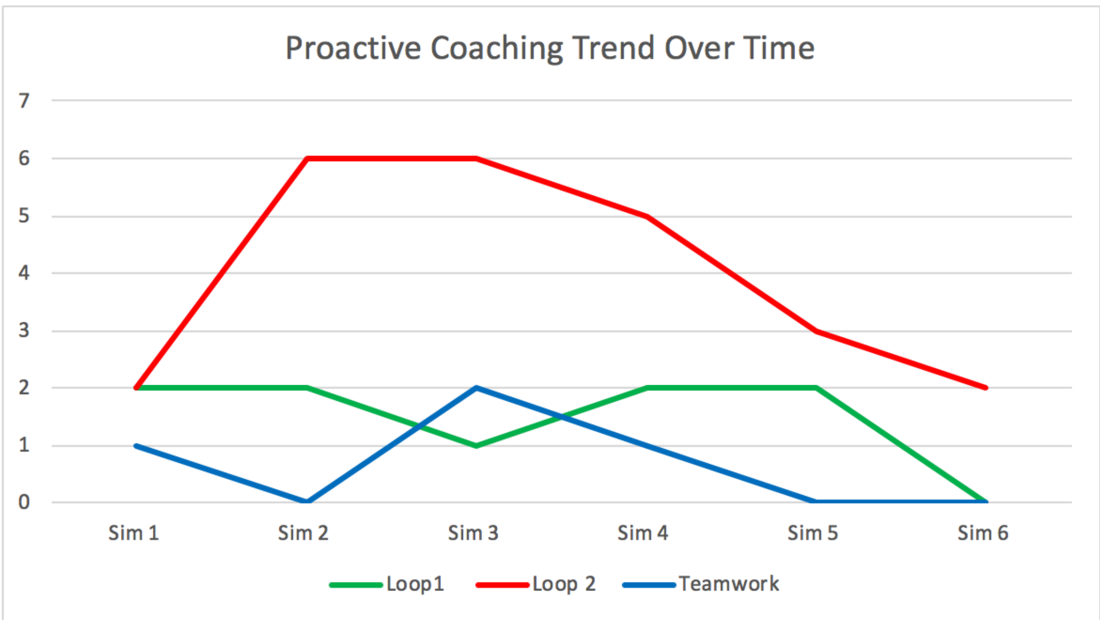

Figure 27. Group 1 coaching trend.

Proactive coaching for Group 1 followed a similar trend to overall coaching, with Loop 1 coaching episodes fairly stable across all six simulations and falling to nil in the final simulation. Loop 2 coaching again started low at two episodes in the first simulation when students were focused on process and then increased as clinical reasoning strategies were required to formulate a clinical management plan. As Loop 2 components became more familiar to students, fewer coaching episodes were required. Weak leadership in simulation three required two coaching episodes.

4.2.1.2 Group 2

Table 26. Group 2 coaching episodes

	Sim 1			Sim 2			Sim 3			Sim 4			Sim 5			Sim 6			Total
	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	
Modelling																			
Monitoring	5	3		1		1	6		3	5	1	3	1	2		1			32
Scaffolding		2	3	2	1	1	4	4	2	1	2	2	2	2	1		2		31
Articulation	1	1		3	2					4	6		3	3			1		24
Answering	1			4	1			1			4			3	2	2	2		20
Interrupting		2		1	1	1											1		6
Totals	7	8	3	11	5	3	10	5	5	10	13	5	6	10	3	3	6		113

Note: Sim = simulation

As an example of how coaching episodes varied across groups, Group 2 had the highest number – approximately 50% more than the other two groups. There were equal numbers of coaching episodes in both loops. The increase in Loop 1 coaching (compared to the two other groups) was primarily because Group 2 either did not appoint a leader or leadership was poor and the coach fulfilled the role of surrogate leader. The number of Loop 2 coaching episodes was on a par with Group 1 but there was a higher percentage of teamwork-related coaching. Coaching related to teamwork occurred in all but the last simulation. As a second example, the pie charts also reflect the increased number of Loop 1 and teamwork coaching episodes for Group 2. In addition, they had a slightly increased percentage of proactive coaching compared to Group 1 and a greater number of major interruptions, one of which was related to teamwork.

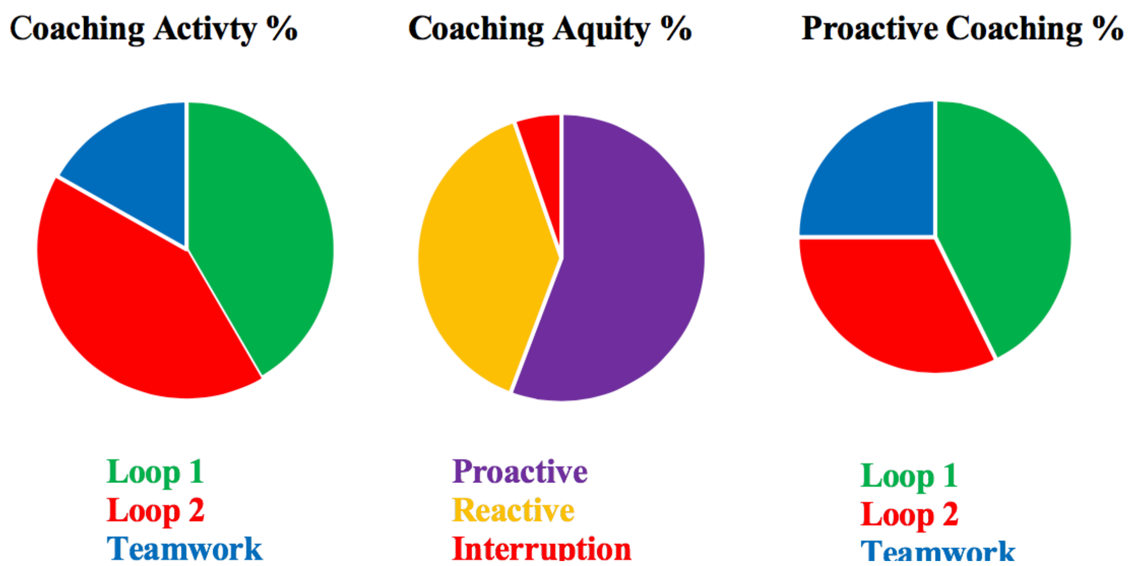

Figure 28. Group 2 coaching data percentages.

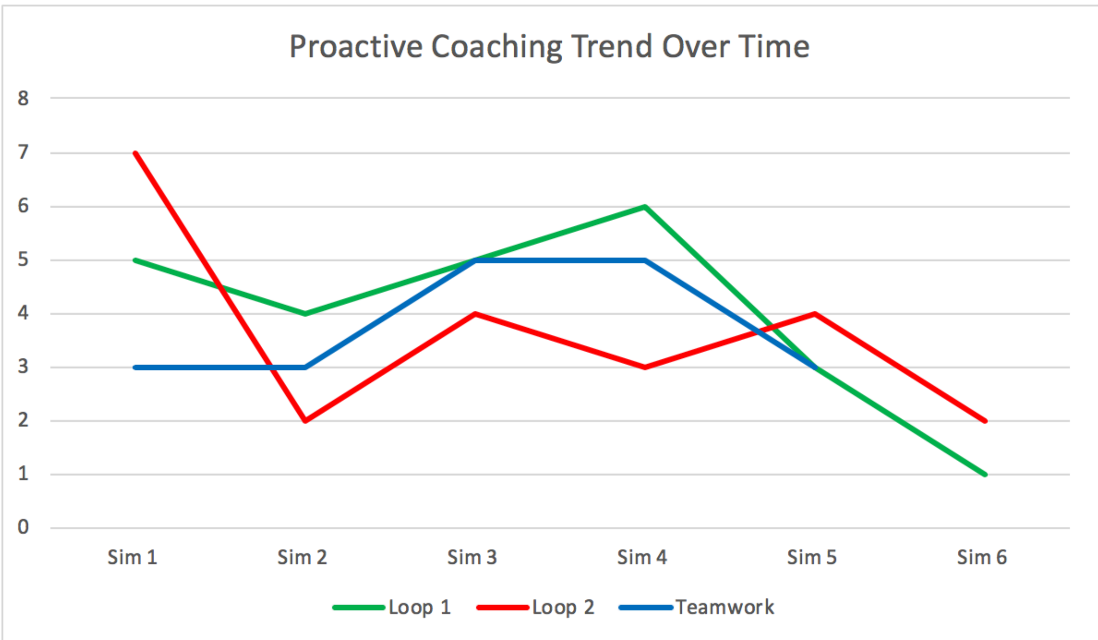

Figure 29. Group 2 coaching trend.

Group 2 needed more proactive coaching episodes in their first simulation than the other two groups because they did not appoint a leader. Extra coaching was required both to provide that leadership and to encourage them to appoint a leader. Loop 2 proactive coaching dropped dramatically in the second simulation as more coaching time was required for Loop 1 and teamwork activities. Loop 1 coaching peaked in simulation four when the group was challenged by two conflicting patient priorities, which they found confusing. Loop 1 and teamwork coaching episodes decreased in the final two simulations.

4.2.1.3 Group 3

Table 27. Group 3 coaching episodes

	Sim 1			Sim 2			Sim 3			Sim 4			Sim 5			Sim 6			Total
	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	L1	L2	T	
Modelling																			
Monitoring	2	1		1	2		2	1		3	3	2	2	1	2	2	1		25
Scaffolding	1	3	2		3	1		1			1		1						13
Articulation	3	1		2	5		1	1			2		1	2			2		20
Answering	1	1			3		1	2			2						1		11
Interrupting								1						1					2
Totals	7	6	2	3	13	1	4	6		3	8	2	4	4	2	2	4		71

Note: Sim = simulation

Group 3 had the fewest overall coaching episodes with three fewer than Group 1. As with Group 1, the majority of coaching was in Loop 2. Group 2 had the most teamwork coaching, followed by Group 3 and then Group 1. Similar to Group 1, the majority of Group 3 coaching episodes were in Loop 2, with the majority of proactive coaching also taking place in Loop 2. As with both of the other groups, the majority of coaching was proactive. There were two major interruptions in Loop 2 and both of them involved management approaches to particular diagnoses. Both Group 1 and Group 2 had major interruptions to the same simulations for similar reasons.

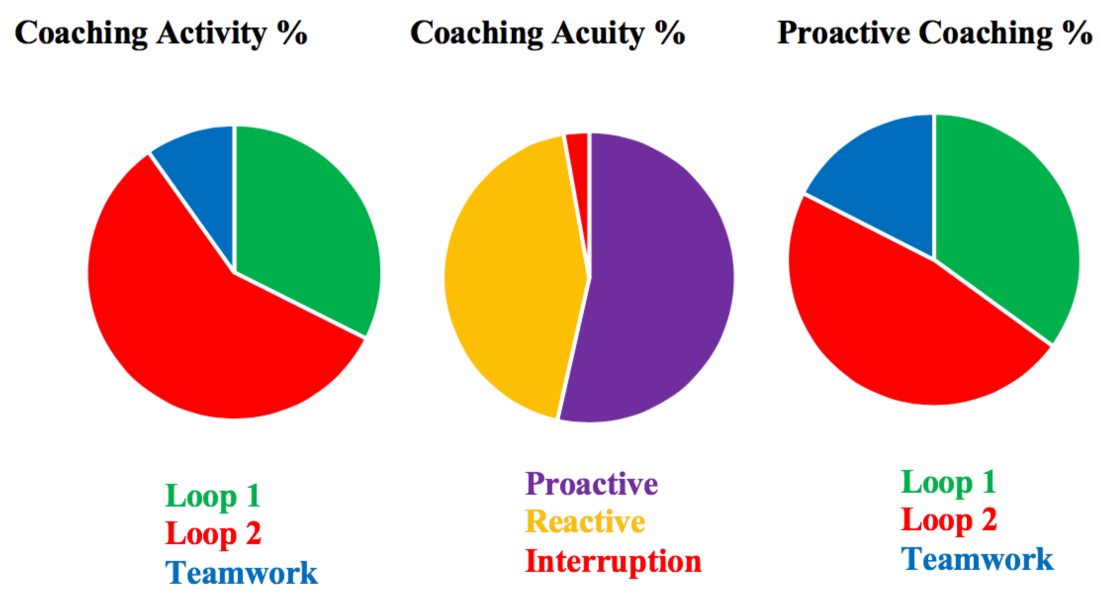

Figure 30. Group 3 coaching data percentages.

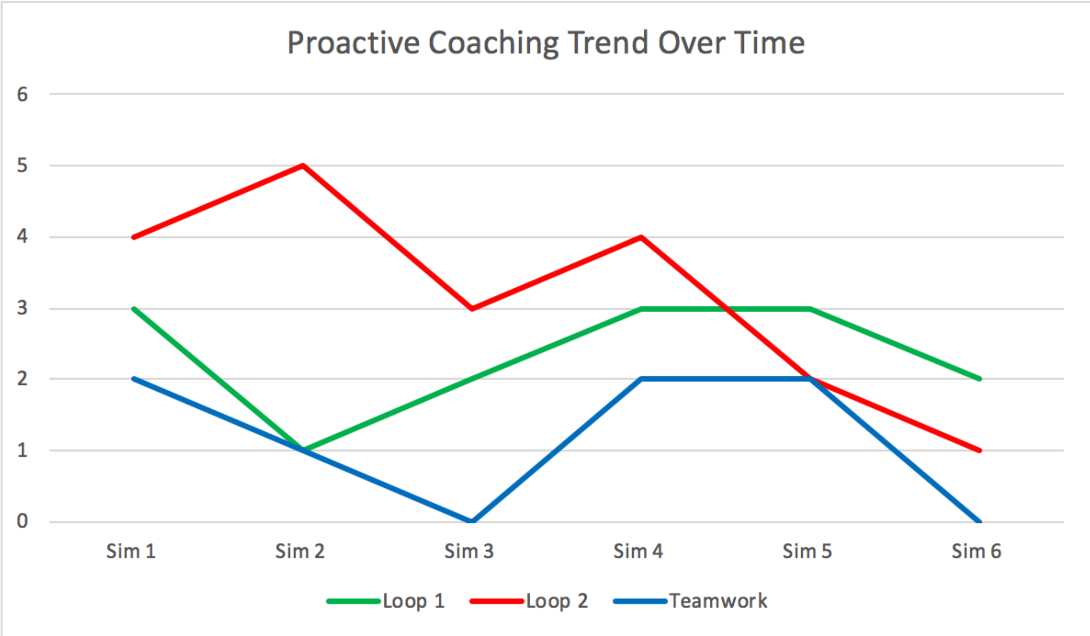

Figure 31. Group 3 coaching trend.

4.2.1.4 Overall coaching episodes

As described in Chapter 2, in relation to choosing the sample group for the study, all 12 groups' first simulations were viewed by an expert simulation colleague and three groups were selected for the study. Selection was based on intuition and expertise without the use of a measurement tool. Interestingly, Group 1 was selected as the 'best' performing group, Group 2 as the 'worst', and Group 3 somewhere in the mid range. Almost as if confirming that opinion is the number of coaching episodes required by each group to support learning, with Group 1 requiring the least coaching support, Group 2 the most, and Group 3 mainly, again, in the mid range.

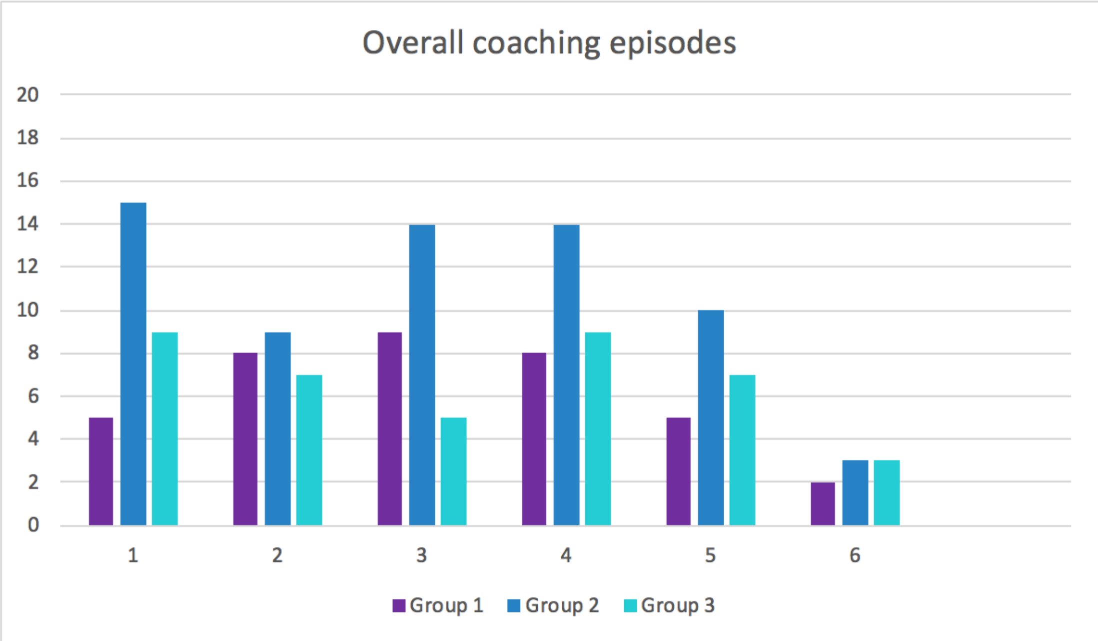

Figure 32. Overall coaching episodes.

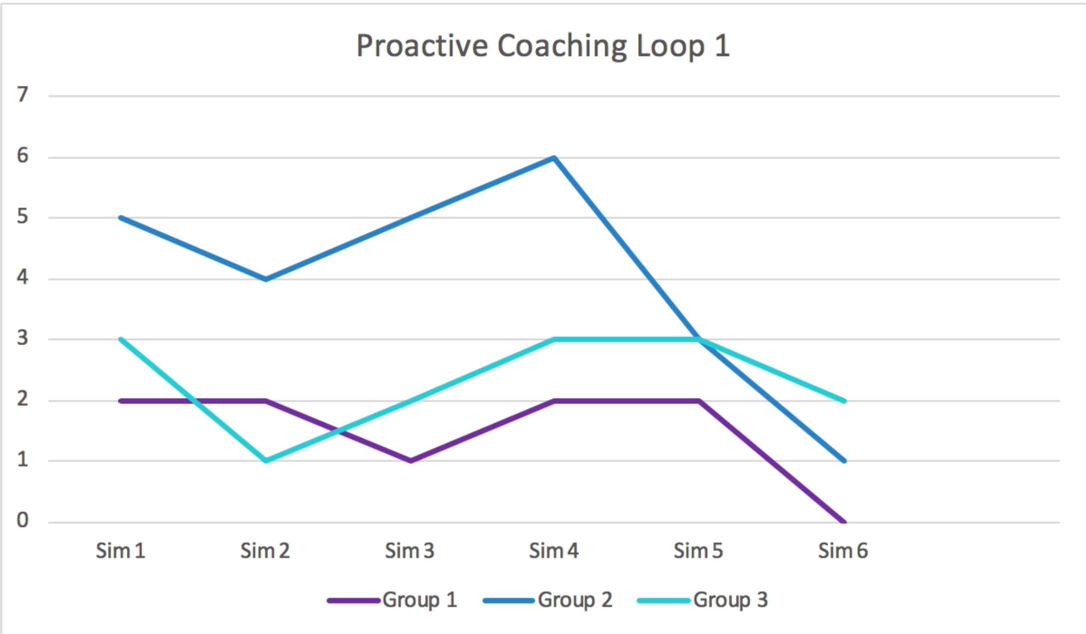

Figure 33. Proactive coaching Loop 1.

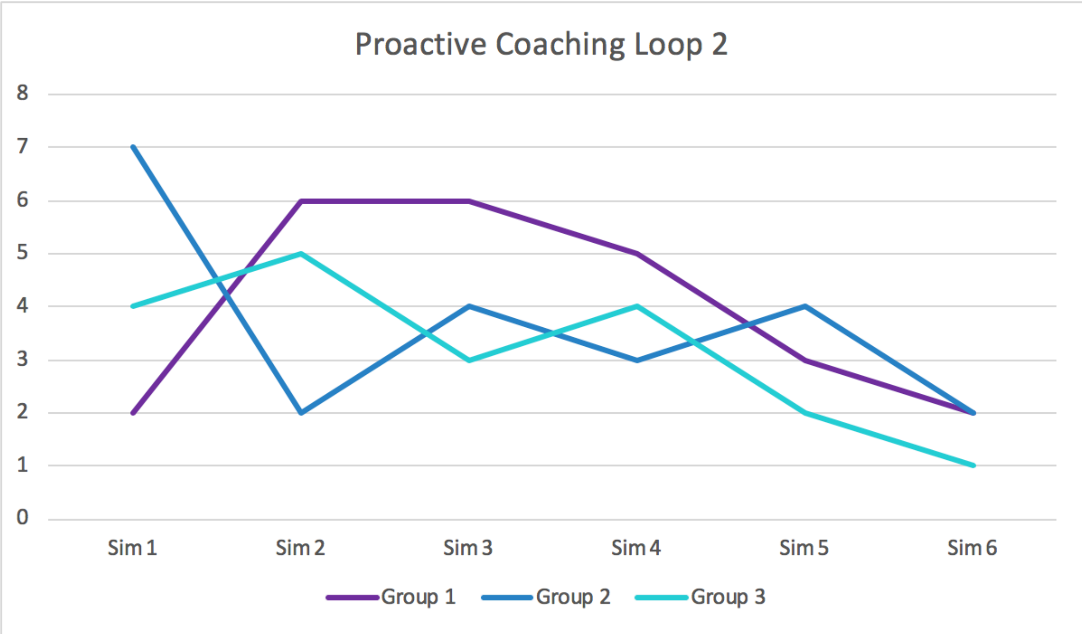

Figure 34. Proactive coaching Loop 2.

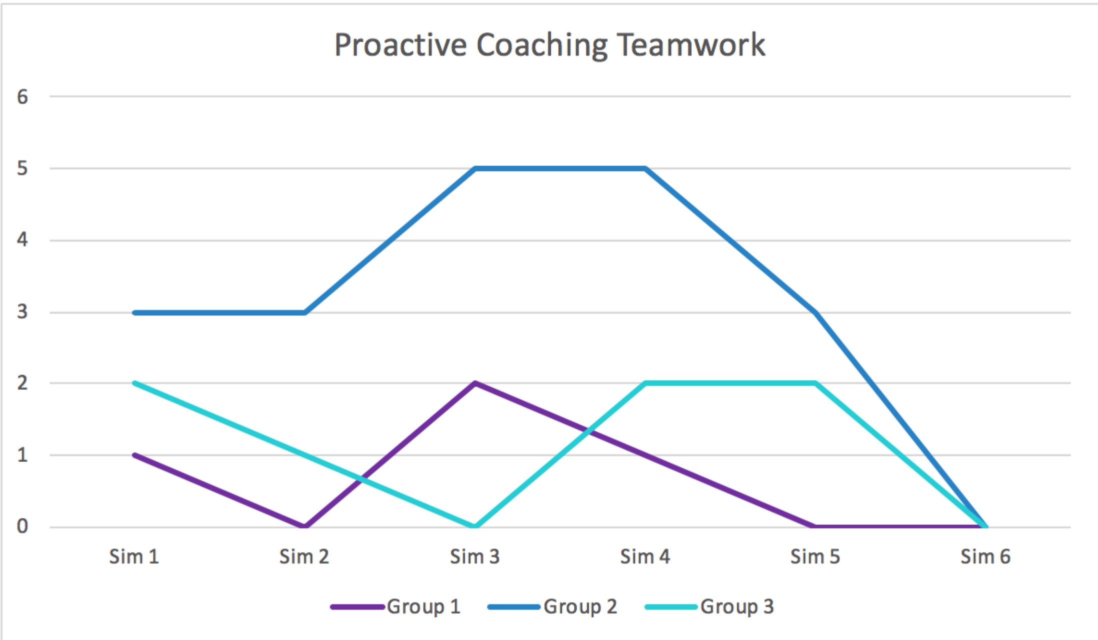

Figure 35. Proactive coaching teamwork.

4.2.1.5 Coaching summary

It is evident from these graphs that the students have progressed in every area and that all groups had particular strengths and weaknesses. Every graph demonstrates that there was either maintenance of, or a decline in, the number of proactive coaching episodes required across all three categories after simulation number four. Despite each group requiring different types of coaching episodes at different times, all groups required fewer interventions in all three areas after simulation number four.

Various coaching methods were employed to effectively guide student learning by providing the skills and strategies that students are initially unable to provide themselves in order to complete the necessary tasks. Over time, the number and type of episodes changed, and the following trends were identified:

- There were equal numbers of proactive and reactive coaching episodes.
- Groups demonstrating effective teamwork traits required fewer Loop 1 coaching episodes as taskwork was organised and efficiently completed.
- Loop 2 components required the most amount of coaching given the diversity of diagnoses and the complexities of different management regimes.
- After two introductory simulations and four case-based simulations, all groups required fewer proactive coaching episodes in all three aspects of patient management – Loop 1, Loop 2, and teamwork – as expertise developed and cognitive support became redundant.

14 (14% of all coaching) coaching episodes required prompting groups to complete the Loop 1 cycle prior to moving to Loop 2, and nine coaching (9% of all coaching) interventions reminding groups to recycle through Loop 1 to ensure that the patient remained stable. Prioritisation of tasks required six coaching episodes (6% of all coaching). In other words, 29% of coaching was focused on the *process* of completing the cycle in order, prioritising accurately and continuing to monitor patient progress.

One aspect of educational design research is the iterative nature of evaluation in order to both test and improve interventions. This period of evaluation is usually conducted at the end of an empirical cycle of implementation when findings are analysed. However, adaptability is necessary and informal evaluation and reflection also take place throughout the whole process with a formative rather than summative basis for adaptation. McKenney et al. (2006) advise that 'given the…real-world research setting, adaptability is essential' (p. 84). Such was the case in this study when alterations to the intended coaching intervention were implemented based on learning needs determined *in action*. For example, several 'major interruptions' were triggered by an obvious lack of students' background knowledge in the setting of acute presentations of a particular diagnosis. While this caused an interruption to flow, these situations meant that the groups were unable to progress through the case and an approach framework was required. These points of adjustment to the coaching intervention occurred in the process of this study, rather than at its completion, and were undertaken 'at need' as it was not possible to predict that they would be required. These revisions were therefore less discontinuous to the simulation program in that they addressed, in a more organic fashion, issues as they arose rather than at a predetermined time. Each incremental refinement retained the evident strengths of the existing coaching model and only sought to adjust those aspects that appeared to demonstrably spotlight areas of specific need. This *in-action* analysis of learning needs therefore related directly to the immediate pragmatic goal of supporting the students' learning rather than as a retrospective analysis.

4.3 Student reflections

Thus far, the focus on taskwork learning has predominantly been concerned with Loop 1 and Loop 2: Loop 1 being adaptive or rule-based procedures for fixing problems and Loop 2 problem-solving to examine the underlying causes of the situation. The focus group interviews provided an opportunity for the third loop of triple-loop learning theory to be addressed whereby students were able to use reflective observation of their video-recorded simulations as a process of conceptualising the transformative progress they had made towards more expert practice. This encouraged them to view learning as an incrementally staged process while providing them with concrete evidence of their own progress.

4.3.1 Second-year focus group interviews

A semi-structured approach was taken for the second-year focus group interviews. From the perspective of the students, inductive coding identified common themes emerging from the focus group interviews that address the research questions centred around their perceptions of the learning progression between their first and last simulations, and the environment in which they learnt. Most comments quoted in Table 28 were a spontaneous result of observing their simulations rather than as a result of the interview questions. Observing themselves in action gave students opportunities for post-hoc reflection as they 'thought out loud' about their problem-solving processes and actions during their simulations. They openly commented about their strengths and weaknesses and were able to identify when their performance was more closely aligned to expert practice.

4.3.1.1 Student comments on learning

Table 28. Student comments on learning

TASKWORK – LOOP 1
Speed and Efficiency – Sim 1

- *Why are we so **slow**?*
- *We are very **slow***
- *It's nice knowing that it's **slow** because it shows you've made improvements*
- *It's **slow** because, one, we're just trying to plot the ABC really thoroughly, and two, we weren't experienced in any of the procedural stuff, so we were **slow***
- *As the year progresses, I'm hoping we do get more **efficient and faster***
- *I can see myself just thinking about **one thing at a time***

TASKWORK – LOOP 1
Clinical Effectiveness – Sim 1

- *We **all** got held up on the airway & breathing and trying to fix that*
- *We were **all** focused on exposure*
- *It was just **ticking the box,** without actually going on to interrogate it*
- *We got better at **thinking AND doing***
- ***Put an ECG on and NOT even interpret it!***

TASKWORK – LOOP 1
Automation – Final Sim

- *We were able to go through the whole thing **systematically** and in parallel*
- *It's great to think about **2 things at once***
- *You don't have to think about it each step … you can stand back and **think about why***
- *We just did it **automatically***
- *We've done it so many times, we **know exactly** what to do*

TASKWORK – LOOP 2
Diagnostic Reasoning – Both Sims

- *We were so slow at making a diagnosis, like critical thinking*
- *Now, everyone thinks about the differentials straight away*
- *We have a lot more discussion about the differentials, we go: 'now we've got this, what's actually happening?'*
- *Thinking about the differentials is a complete flip from the first one*

TEAMWORK

- *No one wants to step and say 'I'll be leader', then everyone is relieved when someone actually does, but later on we realised how important it was to have a leader*
- *We needed a clear leader – no leader, then people were doing different things*
- *Working in a team – like dividing up roles and giving information to everyone else and together – working as a team*
- *The division of labour was more efficient, that freed up more time for the leader to think and not be worried about individual things*

Remarks on student comments - learning

1. Speed and efficiency

Despite the fact that the structured DRSABCDEFG framework of Loop 1 is universally utilised to ensure a rapid and efficient patient assessment, for these learners an understanding of why each component of each step was important was the focus for Loop 1 learning, rather than how long it took to complete the loop. Additionally, time pressure was removed from the second-year simulations. Nonetheless, efficiency in completing Loop 1 patient stabilisation was mentioned by 13 of the 15 students. Although Minnie (Group 3), questioned why they were so slow in their first simulation, other students were able to rationalise why that was and identified speeding up as something to aim for in future simulations. It was gratifying for students to acknowledge that speed had improved over the course of the year and this was confirmed by the video data analysis.2.

2. Clinical effectiveness

Specific examples of completing Loop 1 steps without synthesis of resultant information were identified with students noting that this improved with experience. Later, automation of the steps enabled students to 'think and do' simultaneously. Several students mentioned 'fixation-error'-type examples where they were focused on one aspect of patient management and were unable to progress from there because of it.

3. Diagnostic reasoning

Students' inability to discuss and reason early in the simulated case while simultaneously completing patient stabilisation steps was identified as a major difference between the first and the final simulation where automation of Loop 1 steps was evident. This in turn enabled students to complete Loop 1 and Loop 2 tasks simultaneously when required.

4. Automation

The ability to progress through the case automatically and systematically was attributed to repeated exposure to the DRSABCDEFG framework. 'Chunking' of component steps contributed to automaticity. Students also noted that achievement of process automaticity enabled parallel activities or thinking to occur.

5. Teamwork

Observing their actions, students were aware of the centrality of the leadership role in effective patient management. Appointment of a team leader was considered important from the perspective of effective role allocation, performance efficiency, and information sharing. An unwillingness to step into that role was acknowledged, especially in the first simulation, but the benefits of doing so were mentioned.

4.3.1.2 Student comments on the environment

The comments in Table 29 titled 'Environment' were a result of questions asked in the interviews, rather than the spontaneous reflective comments that contributed to the previous table of results. For example:

What sort of learning do you think occurred during simulation?

How does it feel to imagine being a junior doctor through role-play?

What are your thoughts on the level, or absence of, real-life pressure in the simulations?

THE ENVIRONMENT – Coaching

- *The coach acts as quality controller for all the learning points, as opposed to retrospectively thinking about it and have us guessing*
- *I think you lose out on a learning opportunity (without a coach) – if you miss something, then you miss it and no one brings up the fact you miss it*
- *Having the coach in the room is able to bring things up and manage and make everything more of a learning opportunity*
- *Other clinical schools is a lot more time pressured compared to ours … and they're nervous and don't learn much because it's really intense*

THE ENVIRONMENT – Cognitive Aids

- *We're looking at the poster really frequently (in the first sim)*
- *A lot of people are staring at the board and seeing what we should do next*
- *We threw the training wheels away and it felt really good*
- *No one's looking at the board anymore!*

THE ENVIRONMENT – Supported Learning

- *Sim is the only place in the hospital that brings it in to one place in a team environment*
- *Now you can take the time to learn the process properly, understand what's going on as opposed to just doing it and getting lost*
- *A sense of applying what you know is satisfying because the struggle of the year is not knowing. Sims a great way of showing that you actually know things*
- *This helps to learn by doing, putting it all together*
- *It consolidated a lot of other learning and makes practical use of it – it sticks with me*
- *I learnt a lot about management that I didn't know. I thought I knew a lot of stuff but when you're confronted with a simulation you realise there's a whole heap of stuff you haven't considered.*

Table 29. Student comments on the environment

Remarks on student comments - the environment

1. Coaching

Active guidance from the coach was viewed as supportive in nature and provided opportunities to enhance learning 'in the moment'. It was not viewed as intrusive, nor did it seem to make the situation less authentic for students. It was interesting to note that students had compared their simulation experience to that of their peers at other clinical schools where a different facilitation model exists.

2. Cognitive aids

Students commented on the frequency to which they used cognitive aids (Loop 1 poster attached to the whiteboard) in the early simulations to guide actions. They also felt a sense of satisfaction when they either no longer needed to look at the poster or they dispensed with it altogether.

3. Supported learning

Students appreciated opportunities to combine theoretical knowledge with its practical application, acknowledging that simulation both consolidated prior knowledge and assisted them to also recognise knowledge deficits.

The focus group interviews provided an opportunity for the students to not only express their opinions on the simulation program but also to reflect on their learning through the viewing of their first and last simulations. Comparison of performances in those contrasting simulations added rich detail to the interview data. As an example, students may not have realised how much they had ‘sped up’ or become ‘automated’ in their approaches had they not had visible evidence of it. Viewing the recordings added the extra metacognitive dimension of student self-assessment enabling them to evaluate their own learning and achievements and the added sense of satisfaction associated with that. Opportunities for replaying of performance and subsequent reflection are another dimension to the cognitive apprenticeship (Brown et al., 1989) instructional paradigm deemed important for learners who are in the process of forming their own cognitive model of expertise.

A network model of simulation is illustrated in Figure 36, which represents how the major themes from the focus group interviews have emerged. *Learning* and *the environment* emerged as the two overarching categories of student comments. Learning was identified by students as comprising two distinct activities: taskwork and teamwork. Within taskwork, speed and efficiency, clinical effectiveness, automation of framework application, and clinical reasoning were identified by the students as most important. Within teamwork, leadership and communication were recognised as crucial to the process. Learning support provided through coaching, the provision of cognitive aids, and an overall sense of a supported environment was expressed.

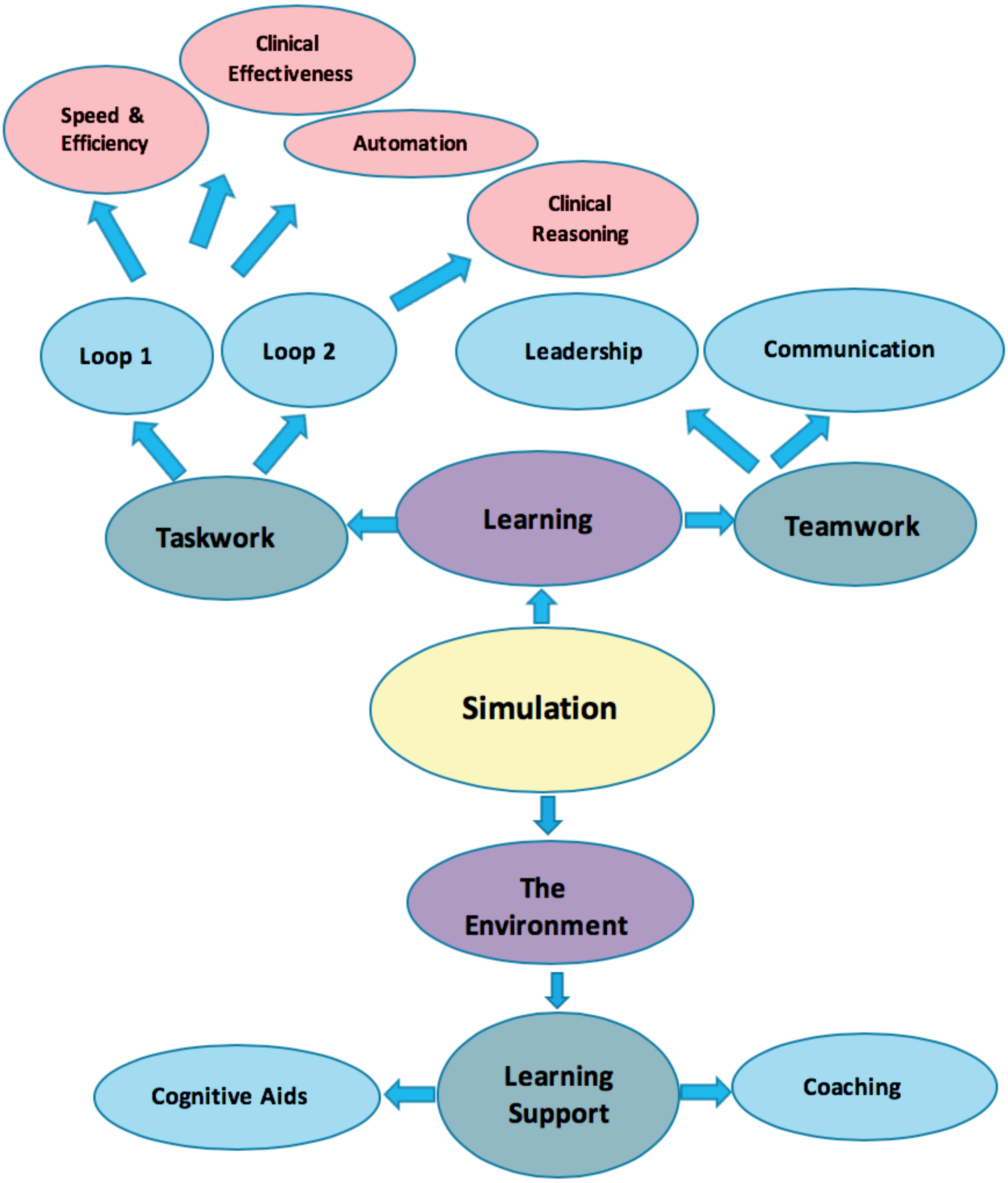

Figure 36. A network model of simulation.

4.3.2 Fourth-year focus group interviews

A second set of semi-structured interviews was organised to explore fourth-year students' reflections on both the simulations from the previous day and the simulation program overall. The following themes emerged through inductive coding and analysis of the data:

- Apprehension about returning to simulation in fourth year

- Feeling 'rusty' after time away from simulation and acute adult medicine
- Retention and subsequent recall of structured approaches to patient management
- Appropriate prioritisation of tasks
- Other reflections on learning in simulation
- A sense of work 'readiness'.

These themes are described and illustrated with representative vignettes over the following pages in this section.

1. Stress and apprehension

> *'I was a little bit **apprehensive** ... I was worried that I might have forgotten a lot'. (Guy, Group 3)*
>
> *'It's inherent **stress** because you forget that it's a sim'. (Cindy, Group 3)*
>
> *'We all want to solve it ... you'd like to think you can manage it, better than all the other groups ... we set our own goals ... where we want to be the best group ... it helps you stay switched on ... we want to do it right and we want to do the best thing'. (Rob, Group 3)*

Increased intrinsic cognitive load (Clark et al., 2006, p. 13) manifesting as feelings of stress or anxiety was mentioned by the students on their return to simulation. Four issues emerged as the causes for this:

(a) Performance anxiety related to how much they might have forgotten after their time away from both simulation and acute adult medicine
(b) The realism of the situation
(c) The acuity of the situation they were confronted with – a deteriorating, unstable patient
(d) The personal pressure they place on themselves to do well.

It was suggested to the students that the added pressures of other team members observing the simulation in real time and the perception that the post-hoc debriefing may have contained an element of assessment added to their stress, but all students denied that this was the case. This sense of apprehension or nervousness did not come through during review of the video recordings. Any hesitations students may have had because of anxiety were managed through effective teamwork and communication, and practical utilisation of resources. Despite the focus of the research being on retention of learning, the fourth-year simulations remain focused on learning and not on assessment. It is important to highlight this to students on their return in an attempt to reduce the performance anxiety they describe as being present. Likewise, the role of the observers is not to assess or criticise in the debriefing but to view and learn from the simulation from a different perspective.

2. Performance

> *'Having time out from clinical exposure meant we were* ***rusty'.*** *(James, Group 1)*
>
> *'Even though we did remember a lot, there were still things we didn't do – we weren't as* ***slick*** *this time round'. (Kane, Group 1)*

One of the issues of interest from a performance perspective is the use of the word 'rusty'. A feeling of 'rustiness' was described by many students due to being away from simulation for a period of time and from a lack of relevant clinical exposure during that time. Unfortunately, at this stage, there is no simulation program during the third year of the medical program during which time the students are away from the clinical school at other locations. Despite their 'rustiness', there was little evidence that students felt they had not retained and retrieved the structured approaches they had previously learnt, nor the rules associated with those structures, as can be seen in the following comments:

3. Using structured frameworks

> *'What we've learnt is just to go back to the* ***structures*** *... going back to the* ***basics*** *here ... useful to fall back on those* ***structures'.*** *(Johnny, Group 1)*
>
> *'... so, I think our sim was reflective of that, the fact that you go through ABCDs even* ***subconsciously*** *...'. (Cindy, Group 2)*
>
> *'The reason all the* ***structures*** *come back to us ... we had that repetition, we had so many sims that I think just a matter of repetition, it actually meant that even though it's eighteen months since we've done it, it was actually able to come back ... like that repetition is actually stored at the back of our minds'. (Lauren, Group 1)*

Students describe both the utility and usefulness of the structured approaches they have previously learnt, and their ability to recall them and use them automatically or subconsciously. Complex problems were approached by retrieving from long-term memory previously processed, organised, and stored information into working memory in the form of schemata. Through repeated practice, schema can be automatically applied, thereby reducing the load on limited working memory resources. The importance of repeated practice is pronounced as a contributing factor towards automatisation of framework application.

4. Prioritisation

> *'We didn't really have a diagnosis for the patient, um, which is not generally what we have been learning ... but it does allow you to be* ***focused and just manage*** *what's in front of you – it's about stabilising someone who can then be moved up the chain'. (Guy, Group 3)*
>
> *'I was thinking of differentials in my head, but it was in the back of my mind and I was thinking more, ok,* ***what can I do now*** *to help and I'm going to figure out diagnosis later'. (Alan, Group 2)*

Students have a clear sense of what their priorities are with regards to patient stabilisation. Conceptualised in this way, focus appears to be on patient stabilisation and the fix-as-you-go rule described earlier and has taken precedence over diagnosing the cause of the problem, which is different from their conventional learning.

5. Retention

> *'I was impressed by how we functioned as a group, coz I thought we would forget a lot of what we'd achieved and what we'd done in second year but I think we* ***retained*** *a lot of that which was good'. (Guy, Group 3)*
>
> *'We all worked well, and we* ***did all the right things*** *... we got the fundamentals down ... all our sim and sim skills and we did it'. (Sally, Group 2)*

Of interest here is the focus on teamwork and the students' understanding of the importance of teamwork in functioning effectively. They successfully retrieved stored teamwork skills, which also appeared to be somewhat automatised.

6. Students' perceptions on the usefulness of simulation

> *'It simulates the real world,* ***how the real world works'.*** *(Rob, Group 3)*
>
> *'I had that realisation in sim yesterday, when it came out that, oh, I have to do that ... as opposed to I would theoretically do that'. (James, Group 1)*
>
> *'The situation is realistic, and* ***you forget it's a si****m'. (Cindy, Group 3)*

From these comments emerges a sense that students are realising, perhaps for the first time, the realty of actually becoming a junior doctor and the responsibility that accompanies that role – an insight into their future. The increased realism and higher acuity of the fourth-year simulations offered a more challenging and dynamic aspect to the situation than previous simulations, thereby adding authenticity and realism. 'How the real world works' is an especially significant comment as it indicates a sense of awareness about the patient problem in the broader context of the 'real world' (e.g., which consultant to call or how to access resources) and that students also value that type of practical learning. Additionally, students acknowledged the role that simulation has played in contributing to the skills they will draw on as a junior doctor in similar real-life circumstances.

4.4 A model of skill acquisition

As discussed in Chapter 2, Dreyfus and Dreyfus (1986) have offered a model of professional expertise that assesses progress through a series of five levels, four of which are illustrated in Figure 37. Student comments on how they viewed their progression in relation to acute management skills are used to populate the figure. These comments were made in the focus groups as spontaneous reactions to viewing their first and final second-year simulations, and at the completion of the final-year simulations, without any mention to the students of the Dreyfus's model.

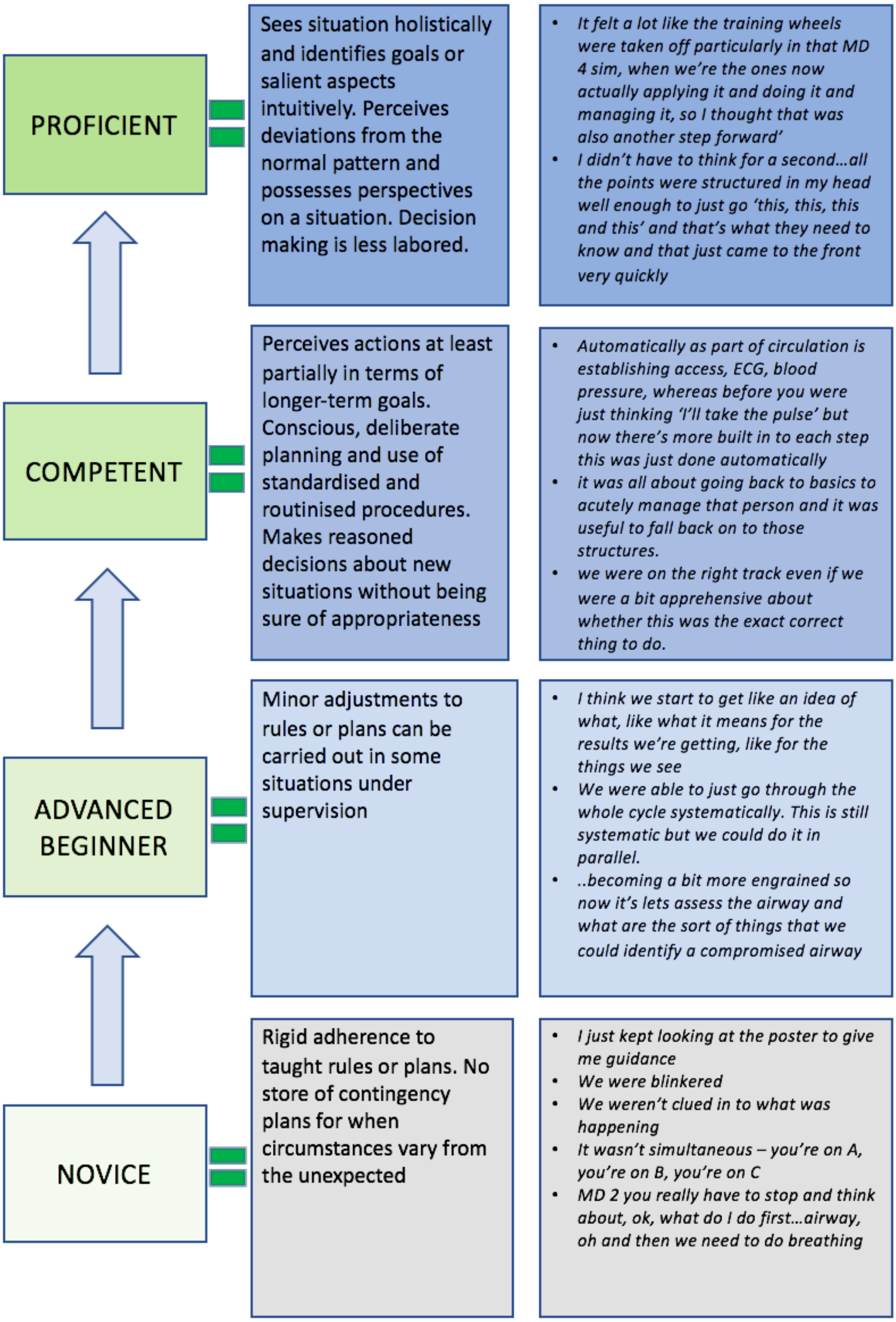

Figure 37. A model of skill acquisition (adapted from Dreyfus and Dreyfus, 1986).

Two important concepts emerge from these comments. First, the importance of learners reflecting on their learning in order to develop a mindset of reflective enquiry and metacognitive strategies, and second, an understanding of the dynamic and continuous nature of expertise development that they recognise in their own transition from novice to competent/proficient practitioner is identified. Finally, medical students in this study revealed the value they place on simulation-based training preparing them for life as a junior doctor managing clinical deterioration, through their reflective comments:

Rose: 'I felt like MD 2, the coursework itself is so much about diagnosis and not management. I feel like the emergency management we learn in sim is actually the learning I retained most from MD 2 and now we're back on the wards, back on the gen med ward and we haven't learnt all that much about very detailed management, um, I struggle a bit with that but then I'm really thankful that because of sim at least in the emergency situation I can do my job now as an intern'.

Kane: 'In future, say, in the country and we're asked to see a patient we've never met before, we've got this practice and this structure that we can fall back on as an approach to it and be like is this … do I need help here … when should I call for help … like, what can I do here … and as an intern, like, where's my limit for what I should and shouldn't be doing or could or couldn't do, which I think is something new we've learnt over time through sims and now we're actually going to put them into practice a bit more now'.

Akshay: 'what we seemed to really retain was the overall structure of approaching the scenario which includes DRSABC, but it also included stuff like the team leader standing back, hands behind your back, even things like calling for help quickly but, um, be more specific about who to call, calling theatre, not just sort of a general 'call a MET call', and leave it at that but, um, do other things as well, taking 5 for 5 all those sorts of things which sort of seemed to have become more subconscious things that you would do, you're not even really thinking about it, when I was handing over and when Guy was handing over on the phone, you just sort of felt you went into a format without really thinking'.

These comments suggest an increased confidence in both teamwork and taskwork abilities not only gained but also, most importantly, retained over time through simulation-based training. By strong implication, the notion of 'readiness' is apparent here. Readiness is defined as 'possessing the taskwork and teamwork knowledge and skills…to establish and sustain competent performance in order to be in control in routine, non-routine...situations' (Kluge, 2014, p. 155). Additionally, automating taskwork and teamwork behaviours makes novices less susceptible to the effects of stress, thus strengthening performance in stressful situations (Kluge, 2014). Many studies have examined the usefulness of simulation in teaching clinical deterioration to medical students, nurses, doctors, and allied health personnel (Alsaba & Brazil, 2018; Bliss & Aitken, 2018; Liaw, Zhou, Lau, Siau, & Chan, 2014). This program, as the results demonstrate, differs in that is embedded longitudinally across a two-and-a-half-year time frame that commences early in medical student training rather than as a one-off or short course taught as massed practice either late in the curriculum or after graduation. There is evidence not only of transfer and retention of skills but also of 'cognitive flexibility' in the appropriate, clinically relevant application of those skills to specific situations (Rentsch et al., 2012, p. 250). Simulation offers learners realistic contextualised practice experiences, which are stored as schema in the context of the settings in which they occurred. The realism of the situation is described here by Cindy:

Cindy: 'It's almost like the inherent stress. For me, it's like this situation is somewhat realistic and for me you forget that it's a sim. You just do what you have to do, and like the good part about sim emergencies is that there's such an easy structure that you don't have to think about anything else, you can just, like, go in to the room and tick off the ABCDEs and be, like, well, I've done as good of a job as I can and the patient is relatively ok and that's part of sim'.

Notwithstanding the fact that the true test of patient management skills will be in real clinical practice, preparing students for such events is a major step in addressing the challenges of clinical deterioration. Of note here is the successful performance of the students, evidenced by the appropriate application of Loop 1 and Loop 2 steps, after an extended retention interval. Additionally, from a learning perspective, Kluge describes the act of retrieval in itself as a 'potent learning event' (Kluge, 2014, p. 139). Reactivation of retrieval mechanisms through fourth-year refresher training after an 18-

month retention interval potentially further extends the benefits of the initial training beyond another 18 months. This conclusion is based on Landauer and Bjork's (1978) theory of expanding retrieval practice where each retrieval opportunity is scheduled after lengthening retention intervals in order to occur 'just in time' before potential skill decay occurred. Applying this theory to the unpredictability of managing a patient in clinical deterioration means that even if these skills are not retrieved for another 18 months, they should still be available for some time after that.

4.5 Summary

Chapters 3 and 4 identify and describe the learning progression of three groups of second-year students as they complete a yearlong simulation program and then return as final-year students 18 months later for further simulations. The chapters thus address the key research question - does a longitudinally embedded patient management simulation program develop medical students' ability to systematically approach patient management, and what evidence is there of transfer and retention of these skills?

After analysis of the learning and coaching observed in the video recordings, and with additional insights from the students, a pattern of learning progression and coaching requirements emerged at second-year level. In essence, the key features of learning progression are:

- Coaching episodes were manipulated due to students' differing requirements for support.
- Leadership style and teamwork practices directly affected successful and efficient completion of Loop 1 and Loop 2.
- Common challenges emerging for all groups were the complexity of the circulation assessment and management, prioritising stabilisation over diagnosis (especially in the early simulations), and the need to often initially treat symptoms rather than underlying disease.
- In general, groups required more coaching in Loop 2 activities due to variations in cases.
- Coaching support in all components of the simulation declined after simulation number four, by which time all groups had become more efficient in their

approach to stabilisation, were able to prioritise steps more appropriately, and were functioning as coordinated teams.

At this level, it is imperative that all three interdependent elements of teamwork, taskwork, and coaching must be dynamically balanced and customised within the action of each simulation to achieve optimal learning and patient outcomes.

Analysis of transfer of learning could only be approached through simulations that were similar enough to previous experiences to make them valid opportunities to demonstrate transfer but novel enough to demand that transfer was evident. Only three pop-ups were able to be organised due to financial and workload constraints. There was evidence of what seemed to be quite straightforward recall of previously developed taskwork schema, but that leadership and teamwork varied greatly as students adapted to different teamwork dynamics than those previously experienced. In summary, Pop-up 1 disclosed strong leadership within a weak team, Pop-up 2 disclosed weak leadership within a strong team, and Pop-up 3 disclosed strong leadership within a strong team. This summation is supported by the effectiveness and efficiency with which each team performed.

The data pertaining to knowledge retention were analysed from the perspective of context-specific framework application; in other words, evidence of prioritisation of Loop 1 and Loop 2 steps relevant to the particular case. Evidence of effective teamwork traits and automatisation of framework application was evident from analysis of the video recordings of the simulations and was supported by the students' own reflections of their performance. In both of the fourth-year simulations, the urgency of the situation was recognised, appropriate help was called for and relevant frameworks applied effectively and efficiently. There is clear evidence that predetermined key criteria for each case were met in a manner that aligns with either competent or proficient in the Dreyfus's model. Although the fourth-year simulations were designed as further learning opportunities, there is a sense, both from the video data and from their reflections, that students were able to use these simulations as a way of checking that prior learning had been retained and was able to be retrieved *in the moment*. There is a sense from the students of 'knowing what we had to do' – a growing confidence in their ability to appropriately manage challenging situations they will face as junior doctors.

Chapters 3 and 4 addressed the findings from the data analysis from the perspective of skills acquisition, coaching implications, and student reflections. Some qualitative data were quantified to clarify findings and present them in a more logical format. A discussion based on these findings follows in Chapter 5.

Chapter 5: Discussion

5.1 Introduction

Chapters 3 and 4 provided a comprehensive account of the findings derived from inductive and deductive data analyses. This chapter contextualises those findings within a design research framework in order to answer the following research questions:

> To what extent does a longitudinally embedded patient management simulation program develop medical students' ability to systematically approach patient management, and what evidence is there of retention and transfer of these skills?

- What taskwork skills are students required to develop in order to manage acute patient management?
- How does teamwork impact on the students' capacity to complete those skills?
- How might instructional design in simulation be developed to support the processes required to develop those skills?
- How can a new role of in-game coach enhance learning in simulation?
- How can optimal conditions for learning in simulation be operationalised?

As a pragmatic–constructivist researcher, the aim of this chapter is twofold. First, having already described the findings from the data analysis in the previous two chapters, I will now attempt to explain the meaning and the implications of phenomena related to learning, performance, teaching, assessment, social interaction, leadership, and other educational issues. Second, from a pragmatic perspective, I will describe, justify, and explain the knowledge generation aspect of the research outputs.

Most importantly, research findings from this study support the use of simulation-based education early in the medical curriculum for the acquisition, transfer, and retention of taskwork and teamwork skills in acute patient management. Repeated reinforcement of patient management frameworks in simulation, in conjunction with observational learning of clinical management in real clinical settings, provides the developmental structure to propel students along a learning continuum from novice to competent/proficient practitioner over a two-and-a-half-year period. This is illustrated using the Dreyfus and Dreyfus (1986) model of skill acquisition in section 4.4.

Taskwork and teamwork skills required to support acute patient management have been identified and described. Processes required to execute those skills are associated with automation, storage, and retrieval of schema developed through repeated instance-based learning opportunities best described by the students themselves in section 4.3.2. The importance of teamwork skills required to successfully execute the taskwork skills in acute patient management have been identified in section 3.2.2. The crucial role of the coach in providing conditions to support a cognitive apprenticeship for students in simulation has been identified in section 4.2. Additionally, in order to address the issues of skills, processes, and cognitive support, learning frameworks and theory-based local design instructions described and explained later in this chapter have been developed as major outputs of the study.

Educational design research is predominantly focused on how to support learning rather than a general approach to education (Gravemeijer & Cobb, 2006; McKenney & Reeves, 2012). As such, it aims to produce concrete outcomes, including improved learning environments and development of best practice guidelines (Reimann, 2011). According to Gravemeijer and Cobb (2006), the analysis in design research is on learning trajectories. In this research, those trajectories were a result of

- a substantiated learning process culminating with students' progression along a developmental continuum
- a demonstrated means of supporting that learning process.

The first major output of this study is the development of *learning frameworks* that have several important applications including supporting planning of simulation sessions, a feedback tool for learners as formative assessment, a teaching aid for novice coaches, and as research data analysis tool.

Second, as a result of the data analysis and findings, evaluation of the two interventions – curriculum redesign and facilitation redesign – now forms the basis for the development of local instructions, or a set of *domain-specific guidelines* describing the optimal conditions required for effective simulation practice, as an output of this research. The Loop 1 and Loop 2 learning frameworks served as a lens for making sense of what happened in the simulations; from those, guidelines for instructional design have been developed based on activities that constitute the effective elements of simulation design and practice. Further underpinning these guidelines are themes emerging from student reflections illustrated in a network model of simulation illustrated in Figure 36 in Chapter 4.

5.2 Research outcomes

5.2.1 Learning frameworks

As illustrated and described in the previous two findings chapters, taskwork learning frameworks were developed to map student actions for each simulated case. The Loop 1 framework was consistently used across all simulations due to its standardised nature. The Loop 2 framework utilised a consistent clinical reasoning approach with varying case-specific content. As a major output of this study, the learning frameworks can be adapted and utilised in the following ways:

1. To support the planning of simulation sessions/programs
2. To provide feedback to learners as formative assessment
3. As a teaching aid for novice coaches
4. To support data analysis.

5.2.1.1 Supporting the planning of simulation sessions/programs

The frameworks contain elements necessary for effective patient management and can be adapted to meet a variety of requirements. Despite the content of the simulations, the frameworks offer a consistent stepwise process of patient management. Identification of the zone of proximal development is essential in planning simulations. The frameworks are particularly useful for identifying and dealing with 'sticking points' of patient management that may be outside that zone and require additional coaching support. An example of this is the circulation assessment at second-year level identified through the data analysis. Once identified, particular attention can be paid to those more challenging components through a variety of instructional design methods, such as modification to a scenario through a pre-simulation workshop on a particular topic or a reduction in element interactivity. For novice learners, high interelement activity exceeds the limits of working memory capacity (Clark et al., 2006). Element interactivity, where several knowledge elements must be coordinated in working memory to complete a task, could be reduced by initially eliminating a clinical aspect of the case. Repeated opportunities to practise addressing the more challenging aspects of cases can be offered by reintroducing that element in subsequent simulations. An example of this would be having addressed a problem of low blood pressure with intravenous fluids, each time the blood pressure was rechecked it remained normal. In this way, the process of recycling is completed but the blood pressure does not need further consideration. In subsequent simulations, as expertise develops, this can be varied with ongoing blood pressure challenges where it does not respond to intravenous fluid and other options must be considered.

5.2.1.2 A feedback tool

Formative assessment (assessment *for* learning), as opposed to summative assessment (assessment *of* learning), can guide the coach in planning for learning and to help students identify areas for further development. All of the steps in the frameworks are 'event points' where group performance is checked against components of the pre-identified desirable behaviours. The frameworks can be used as formative assessment tools to indicate whether learners meeting the learning goals and if not, then what is required to fully reach them, thus promoting reflective practice. Printed copies of the learning frameworks could be used as checklists either by the coach or the students to highlight performance aspects requiring attention as a continuous assessment to guide development. Students could identify their own learning goals for subsequent simulations from the framework data.

5.2.1.3 Supporting coaching

Knowing how much coaching is needed is probably one of the more challenging aspects for novice coaches. Learning needs to be supported with an explicit instructional goal in mind so that learners receive just enough support to remain in a state of flow, but not so much that it is detrimental to learning. Using the learning frameworks to identify where students are currently placed from the perspective of their zone of proximal development informs coaching requirements. As discussed in section 1.8.2, within serious gaming, where the in-game coach model originated, a variety of coaching styles are evident. Some coaches are very active, whereas others let the game run without too many interruptions (Alklind Taylor, 2014). A balance needs to be struck between appropriate interventions and ensuring a state of flow. Too few interventions may lead to an increase in extraneous cognitive load due to student frustration, or to the risk of negative transfer. Negative transfer occurs when there is 'a mismatch between a training system and the actual task' (Liu, Blickensderfer, Macchiarella, & Vincenzi, 2009, p. 50). This could occur if a student's action was not corrected by the coach, and that action was subsequently considered correct by the student and then transferred to real-world practice. An example of this would be students failing to recycle back through Loop 1 to ensure patient stability. This could potentially occur if students are engrossed in Loop 2 activity and the coach does not want to interrupt flow. The coach needs to decide *in the moment* which actions require correction at that time and which can be left for subsequent simulations.

The greatest challenge for the coach is monitoring all activities occurring simultaneously in action, which requires a well-developed sense of the coach's situation awareness. For example, if one student needs assistance with a psychomotor skill such as inserting an intravenous cannula, it is easy for the coach to miss an important discussion being held between other students at the same time. Facilitator situation awareness is described by Alklind Taylor (2014) as 'being aware of what is happening in the learning space and understanding how that information can be used to assess learners' progress in relation to current and future learning goals' (p. 190).

Having advanced warning, via the learning frameworks, about potential critical points requiring the coach's attention can assist in managing situation awareness. Also, this aspect of in-game management is further aided by students having the prerequisite knowledge and psychomotor skills required for the case prior to entering the simulation so that coaching attention is not distracted by them.

5.2.1.4 Supporting data analysis

A form of cognitive task analysis was undertaken to determine the desired learner actions and populate a learning framework. Rather than just using the framework as a guide to what should be achieved, populating it with time stamps provided a basis for analysing trends in student actions. For example, it highlighted the somewhat disorganised undertaking of the circulation assessment through plotting a time chart indicating back and forth movement through the step rather than a smooth progression of entire task completion. Subsequent comparison between groups then highlighted common trends.

5.2.2 Local instruction guidelines

The goal of the local instruction guidelines is to inform others who are interested in the implications of educational design research for their own teaching programs (Gravemeijer & Cobb, 2006) and to contribute to best-practice standards in simulation-based education. They are not intended as a 'recipe for success', but to guide and assist others in the development, modification, and application of instruction guidelines in their own domains (McKenney & Reeves 2018, p. 73). This section describes each of the guidelines separated into taskwork, teamwork, and cognitive support, justifies each one, and includes explanations, implications for coaching, and a rationale. The guidelines are summarised and presented in Figure 38. One overarching guideline regarding the simulation program underpins all others in relation to their relevance and application. These guidelines are only applicable in the setting of an integrated, longitudinal, and distributed simulation program that affords opportunities for learning progression over time. They do not apply to one-off, occasional, or massed simulation sessions that do not promote long-term retention of learning.

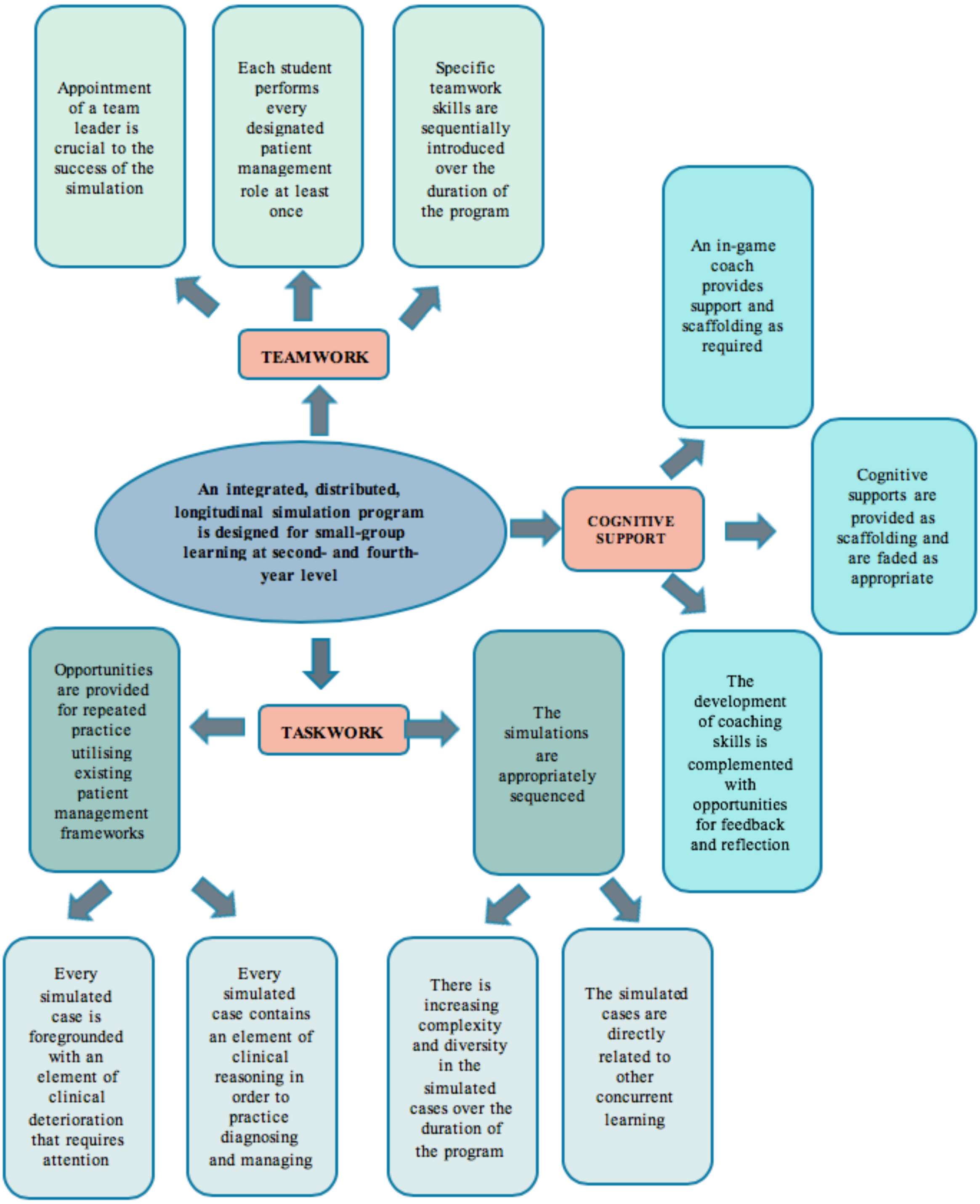

Figure 38. Local instruction guidelines.

5.2.2.1 Generic

1. An integrated, distributed, longitudinal simulation program is designed for small-group learning at second-year and fourth-year level (or at midpoint and endpoint of clinical training).

Principle: A long phase of practice opportunities with ‘overlearning’ strategies coupled with increasing complexity and diversity of cases is required for long-term retention of learning.

Justification: Expertise is formed through experience. Taskwork and teamwork skill development depends on exposure to repeated instances of patient management situations.

Explanation: When the learning objective of simulation is to teach learners the practical management of a particular presentation, such as asthma, then a one-off simulation session sequenced appropriately with a didactic component may add another dimension to the learning. However, when the objective is to teach a structured approach that is transferable to all patient management situations, including the patient who is short of breath and *may* have asthma, then a distributed learning approach is required. In other words, in the first example, the problem (asthma) drives the learning rather than as a trigger for previously learnt concepts. Repeated opportunities to practise both taskwork and teamwork provide a platform for progression along a learning continuum that results in transfer and long-term retention of learning. Repeated exposure to simulation at the clinical endpoint of training provides opportunities for refresher training and ongoing extension of retention.

Implications for coaching: The longitudinal nature of the simulation program coupled with the distributed nature of skills teaching requires coaching staff to continually monitor and assess the learner’s zones of proximal development. This ensures that learning opportunities, along with theory-required scaffolding, are sequenced according to learner needs.

5.2.2.2 Taskwork

2. Opportunities are provided for repeated practice utilising existing patient management frameworks

2a. Principle: Every simulated case is foregrounded with an element of clinical deterioration that requires attention.

Justification: Junior doctors believe they are inadequately prepared to manage clinical deterioration.

Explanation: The frameworks are made visible to students through worked examples, cognitive aids or through prompting of previous learning by the coach. In the early simulations, students are required to fully complete Loop 1 steps prior to moving on to Loop 2, even if the diagnosis is obvious. As expertise increases and students are able to prioritise Loop 1 and Loop 2 steps, there can be movement between the two loops.

Coaching implications: Key concepts are repeatedly reinforced by the coach through strategies aimed at correct prioritisation of steps. The key objective is automation of Loop 1 steps, which requires 'holding back' students in that loop until there is understanding of the Loop 1 rules. At this *cognitive* stage of skill acquisition (Anderson, 1982) students need to 'think about' every step and are heavily dependent on cognitive aids for guidance. The students will complete each component of every step individually rather than as a whole step. For example, B will be broken down into respiratory rate, work of breathing, oxygen saturation, etc. Also, each step will be completed sequentially, meaning that the student on A finishes, then the next student on B steps up and completes, and so on through the cycle. This is a typical progression as load on working memory is heavy at this stage. However, extraneous cognitive load can be decreased by having students remain focused on automation of steps (Clark et al., 2006). It is crucial to reinforce the fix-as-you-go rule at this point because students are at risk of focusing on cycle completion as a 'tick-box' exercise rather than addressing issues as they arise. Additionally, environmental stressors such as multiple data streams – the patient, the patient monitor, the coach – can initially overwhelm students. In students' ward-based encounters the only data source is the unmonitored, non-deteriorating patient. This may account for students overlooking patient monitor data (such as the ECG) and only reporting back patient-based findings ('the chest is clear').

Once these components are being completed smoothly, it is important to support students to progress onto an *associative* (Anderson, 1982) stage, which usually occurs at around simulation number five. In this stage, individual components of a step are combined or 'chunked' into larger units (e.g., the entire breathing assessment is done as one step and fixed at the same time). Additionally, one step smoothly cues the next and students are encouraged to work simultaneously to improve efficiency. These associative steps require coaching and demonstration. By now, students are starting to apply the rules but often require coaching confirmation. As students experience more simulations, they begin to recognise meaningful, common patterns and move towards becoming an advanced beginner whereby they apply the rules in new situations, albeit with some hesitation. Having students articulate their thinking is a useful way to explore, and correct if necessary, their plan. Of particular challenge is the circulation assessment, from both a completion perspective and a fixing perspective. Most likely because of the high number of components in the step, key data are often overlooked or omitted. Second, determining the volume and rate at which intravenous fluids need to be administered to fix the circulation needs considerable coaching input. Additionally, students often overlook regularly rechecking the blood pressure – perhaps again it is treated as step to be 'ticked off' rather than an ongoing issue to be monitored. This resulted in 'ageing' data being incorrectly incorporated into decision-making. Again, articulation is an effective way to both prompt students and keep them in flow by simply asking, 'What do you think of the blood pressure now the fluid is running?'

With practice and appropriate scaffolding, an *autonomous* stage is finally reached whereby students are completing the whole Loop 1 cycle fairly independently without requiring conscious control (Anderson, 1982). In the setting of clinical deterioration, working memory resources are required in order to start Loop 2 processing. If the Loop 1 cycle can be chunked from its nine individual components of DRSABCDEFG into one automatic process, working memory is freed up in order to learn about the situation (for a medical student) and to manage the situation (for a junior doctor). After demonstrating automation and completion of Loop 1 steps, merging of Loop 1 and 2 is encouraged and promoted. Coaching is required at this point to help students identify which steps are important, how to notice if the situation is different from previous experiences, and how to adapt the steps.

2b. Principle: Every simulated case contains an element of clinical reasoning in order to practise diagnosing and managing.

Justification: Students need longitudinal experiences, linked to concurrent learning, that identify explicit clinical reasoning processes.

Explanation: Previous clinical reasoning learning is reinforced through a systematic and sequential approach. Appropriate Loop 1 steps must be completed before Loop 2 is entered. Loop 1 recycling must also occur.

Coaching implications: In the early stages of the simulation program, students have limited knowledge on which to base their reasoning. Their basic clinical communication skills make eliciting relevant patient information challenging for them. Adhering to a fundamental three-phase reasoning strategy is a good starting point – data collection, followed by problem presentation, and then hypotheses generation. In the early simulations, clinical reasoning is disorganised and coaching initially needs to focus on the process itself. Although basic rules, such as linking investigations to differential diagnoses, are helpful, considerable biomedical knowledge is required for students to progress through the reasoning process. Applying such knowledge in context is also a new skill to be mastered, and coaches need to be aware of the high cognitive demand required to learn and enact these new steps. Coaching is also required to assist with analysis of the relative weight of specific data in supporting or refuting differential diagnoses. In the early simulations, all situations will be problematic, and according to Schwartz and Elstein (2008) generating a small set of differential diagnosis is sufficient at this stage.

Often a mnemonic such as AMPLE (allergies, medications, past history, last ate/lifestyle, event) is a useful starting point in history taking until the patient's condition is stable enough to undertake a more formal patient interview. From there the questions can become more targeted when event is explored. Adding further mnemonic support, for example, SOCRATES (site/onset/character/radiation/associations/time course/exacerbating/relieving factors/severity), to explore pain is also a structured way to promote targeted history taking. It is important to again remember that learning these steps carries a heavy cognitive load, so in the early simulations, remembering the steps without processing the information gained from them is perfectly reasonable. Coaching questions such as 'What do you make of that information' prompt students to think beyond data collection.

Although Loop 2 steps follow a sequence, unlike Loop 1 the detail is case specific requiring a broader range of coaching techniques. In particular, students are very keen to make a diagnosis, which often means they either risk premature closure on their diagnosis or that ongoing patient stabilisation is overlooked. From the perspective of premature closure, articulation once more plays an important role. Asking students about their approach to a certain sign or symptom is one way to explore their thinking. Following that up with a divergent question such as 'What other causes might you consider?' often forces consideration of alternative possibilities. It is important to explore students' thinking even if they have the correct diagnosis in order to encourage metacognition. Developing a reflective approach to problem-solving is one strategy considered effective in avoiding diagnostic error such as premature closure (Croskerry, Singhal & Mamede, 2013).

Clinical reasoning in Loop 2 requires more diverse coaching due to case specificity. Unlike Loop 1 where associated rules assist in patient stabilisation, Loop 2 requires 'domain-specific knowledge' to support problem-solving. In most cases, students can describe management of a given condition but struggle both to prioritise their management plan and to appreciate a junior doctor's scope of practice. Prefacing all management plans with 'as a junior doctor you would do X' is an important mantra for coaches to reinforce in order to give students a sense of their practice limitations. The practical application of a management plan often differs from the textbook version. At this point, the coach's expertise and experience can be externalised in the spirit of the cognitive apprenticeship by making their thinking 'visible' in order to share knowledge.

Although administration of medications is not usually a junior doctor's role, it is a fun aspect that adds to the simulation action and also contributes to a sense of completion of the simulated case. Often, the effects of the drug can be demonstrated either through a change in patient symptoms or patient status on the bedside monitor, also adding a sense of satisfaction to the students' reasoning processes.

Medical students are more used to *learning* without opportunities for *doing*, so *learning and doing* simultaneously is also a new skill to be mastered. In this situation, coaches need to strike a balance between recognising the support required to achieve the immediate objectives (such as learning the process) and what can be deferred to later simulations once steps become more automatised. One factor mitigating the challenges to continuous in-game monitoring by the coach is the fact that due to the longitudinal aspect of the simulation program offering repeated opportunities for students, uncorrected actions can be noted by the coach and addressed later. Those actions can therefore be introduced into subsequent simulations as learning objectives: *'Today we will focus on recycling through Loop 1 steps during Loop 2'*. Another mitigating factor in this situation is that medical students, unlike many other healthcare students, will not be responsible for real-world action until they are junior doctors so many further opportunities exist to build on learning.

3. The simulations are appropriately sequenced.

3a. Principle: There is increasing complexity and diversity in the simulated cases over the duration of the program.

Justification: The simulations are characteristic of Vygotskian zones of proximal development in which the learners' tasks are slightly more challenging than they can manage independently (Vygotsky, 1978).

Explanation: Although the simulations are linked to corresponding clinical placements and the cases are therefore standardised, task content, complexity, and interactivity can be modified accordingly. Optimal learning conditions in simulation depend on three interdependent and non-static factors that need to be constantly monitored by the coach in relation to increasing complexity and diversity:

- Maintenance of flow
- Attention to the zone of proximal development
- Appropriate cognitive load.

Experiencing and maintaining a state of flow assists learners to become immersed in target activities. To remain in a state of flow, novice learners need challenge–skill balance otherwise they will experience anxiety, which in turn increases extraneous cognitive load. Likewise, as learners become more experienced, they risk becoming bored if the simulation is not challenging enough. In other words, to experience a continued state of flow, learners must be encouraged towards higher levels of performance at the appropriate pace (Alklind Taylor, 2014). Learners also need to experience a sense of control through guided coaching support with few interruptions. Similarly, learners also need to be within their zone of proximal development in order to remain appropriately challenged. Once student learning progresses beyond that of a novice, instruction should be dynamically adjusted to accommodate increasing expertise. Appropriate fading of scaffolding occurs through increasing case complexity and/or withdrawal of coaching support while continuously maintaining a state of flow.

Complexity can be increased in one of two ways. Either the clinical complexity of the case can be increased or the number of components in the case can be increased. For example, a more complex heart attack case may include an added complication needing to be managed or may include an extra component such as the patient being found on the floor after collapsing. An important consideration when planning increased complexity in simulation design is that as novices' reasoning skills develop, practical experience with 'typical patients' (patients whose signs and symptoms are those described in textbooks) is preferred over experiences with 'atypical' patients (Boshuizen & Schmidt, 2018). In other words, care needs to be taken when altering complexity such that the case remains 'typical'.

According to Clark et al. (2006), learners end up with a much broader set of skills by experiencing a diverse range of contexts. *Adaptive capabilities* such as recognising changes in task priorities are more likely to be enhanced by variability (Kozlowski, 1988, p. 120). Diversity is provided through linking simulations to clinical placements resulting in a mix of medical, surgical, and emergency patient presentations. Kluge (2014, p. 141) describes three added benefits of increasing the diversity of the simulation experiences:

1. Variations to the learning experience benefit long-term retention by increasing storage and retrieval strength. This is due to retrieval being more difficult because the cues from prior learning differ to those available in current learning. Increase in retrieval difficulty increases retrieval strength.
2. When a new experience occurs in a slightly different manner, it is linked to different retrieval cues and contexts, thus increasing the generalisability of the newly learned knowledge and skill.

3. Variation of the task is assumed to force the learner to engage in higher order learning such as recognising similarities and differences from other experiences.

From the perspective of cognitive apprenticeship, increasing the diversity of simulations in association with increasing complexity ensures beneficial sequencing of activities.

Coaching implications: Simulations need to be adjusted to accommodate expertise development in the groups through increased complexity and diversity. Each groups' zone of proximal development may vary. Assistance is provided to students as needed through cognitive apprenticeship coaching methods described in Chapters 1 and 2. Coaching requirements and styles differ both within and between groups. Case complexity can be modified *in action* if required. For example, if students are struggling due to task overload, the coach can offer to complete a more difficult task on behalf of the group or simply eliminate the task from the case.

As expertise develops, coaching episodes and the need for cognitive aids decreases as students develop complex schemas to replace that support. Coaching requires an accurate assessment of group progress in order for scaffolding to be appropriately faded through continuous monitoring and assessment. On the other hand, there may be an unexpected rise in coaching episodes due to increasing complexity and diversity placing extra demand on working memory. Again, this calls for *in-action* adaptation to either components of the simulation or the amount of scaffolding required, or both. The coach needs to be mindful of previously taught concepts and allow time for student recall.

According to Kluge (2014), the focus of the coach is 'the selection and compiling of the instances in a temporally sequential manner, which a novice works through and experiences in order to extract patterns and derive cues, and from which he/she learns cue configurations, decisions and utilities' (p. 173). The early simulations are opportunities for completion of simple tasks associated with each step, including making simple associations between stimuli and responses. Although time is an important consideration in the development of expertise, learners also need opportunities to accumulate a varied set of experiences (Crandall et al., 2006). More complex tasks with high interelement activity are introduced at the coach's discretion. In the early simulations, groups became distracted from their systematic approach if the situation was further complicated by patient comfort issues such as nausea, pain, or a high temperature. Groups then found themselves with conflicting priorities – that of patient comfort and that of patient stabilisation – and were unable to prioritise. Despite having a large enough team to deal with both issues simultaneously, groups were unable to manage more than one issue at a time and this added complexity was potentially detrimental to learning.

This is an example of the complexities of both real-world practice and the emotion-charged reality of a patient in discomfort – neither of which these students have encountered before. From the perspective of instructional design, there were too many elements present, which in turn increased extraneous cognitive load. In order to make decisions about patient priorities, students need to recognise familiar elements of a situation, usually based on past instances, and use that knowledge to evaluate the current situation (Kluge, 2014). Naturally, such knowledge requires significant time to develop, making it difficult to differentiate between a clinical problem that requires immediate attention and one that is less acute. Coaching episodes to rationalise conflicting priorities assists students in subsequent decision-making when faced with similar circumstances.

3b. Principle: The simulated cases are directly related to other concurrent learning.

Justification: The learning is contextualised within the broader curriculum in order for students to understand the relevance of the case. Opportunities are provided to apply domain knowledge, relevant to specific clinical placements, to realistic problem contexts. Domain-specific knowledge and associated procedural skills are a fundamental prerequisite for simulation training.

Explanation: Each simulation coincides with the student's clinical placement rotation (medicine, surgery, or emergency medicine) in order to complement real-world learning offered through tutorials and ward-based activities. Linking of mental models developed in simulation to real-world contexts offers opportunities for cognitive transfer through direct linking of simulation experiences to real-world experience.

Coaching implications: Students often observe fundamental differences in reasoning approaches in clinical practice compared to what they have been taught. Experts often use abridged strategies that are not made obvious to students. This is often referred to as ‘tacit knowledge’ that experts can call on but cannot always verbalise how they do it (Polyanyi, 1966). Simulation offers opportunities to examine this by making explicit the underlying basis of real-world reasoning. ‘Rules of thumb’ or heuristics can be demonstrated and explained during simulations providing valuable insights for students.

Due to the homogeneity of the groups, some advanced skills may be out of the group’s range of expertise, especially in the early simulations. Interruption to flow and increased extraneous cognitive load due to a lack of knowledge reduces the efficacy and efficiency of simulation experiences. Activities, such as psychomotor skills, outside students’ zones of proximal development potentially lead to student frustration and lack of engagement if the task is too difficult. However, the presence of an in-game coach can overcome this issue by completing the task for the students, thus allowing them to progress through the case. As some propositional and procedural knowledge acquisition is linked to clinical placements, it is important to situate simulation learning within that broader context.

Explanation: The aim of simulation is not to teach textbook knowledge, but to guide learners in reconceptualising that knowledge into practical or clinical knowledge. Relevant prerequisite prior knowledge is mandatory for optimal simulation outcomes. In line with simulation objectives and supported by cognitive apprenticeship theory, learning is based on the requisite skills required to solve similar problems in new situations rather than the learners mastering knowledge content.

As discussed in Chapter 1, maintenance of flow is required for immersion in an activity in order to successfully complete it and ultimately leads to skill development and knowledge acquisition (Challco & Andrade, 2016). Major interruptions to simulation flow identified in the data analysis were due to students’ lack of textbook knowledge around two acute patient presentations. Additionally, procedural or psychomotor skills, such as intravenous cannulation, are also required to complete the case. As discussed in Chapter 1, the objective of simulation-based training is the *application* of knowledge and skills particularised to the situation rather than the learning itself.

Complementing the variety of clinical learning that students are experiencing with associated simulations ensures diversity of conditions under which students are applying their knowledge and skills. Linking simulations to clinical placements also affords opportunities for students to directly relate simulation experiences with observational learning in the workplace. A major goal of simulation is the transfer of knowledge to new situations, which may enhance workplace learning through a deeper understanding of what students observe in clinical settings.

5.2.2.3 Teamwork

Analysis of the teamwork component of the simulations identified two overarching themes. The first theme is the importance of effective teamwork behaviours contributing to optimal patient outcomes. This was evident from several perspectives, in particular the need for the initial appointment of a team leader. This one factor was the strongest determinant in successful completion of Loop 1 and Loop 2 activities. Other teamwork requirements such as effective communication, although important, could be built on as the simulations progressed in such a way as to not overload a novice team focused on learning new frameworks of patient management. Salas et al. (1992) argue that teamwork skills develop most effectively and efficiently after individual team members have developed individual taskwork skills. In other words, some threshold of taskwork development needs to have occurred before teamwork skills are introduced.

Second, the other interesting theme to emerge was that of team cognition. Fiore and Salas (2009) describe team cognition as 'being related to the process of information encoding, storage and retrieval, such that a group product emerges' (p. 235). They further state that team cognition 'can describe a process such as the transmission of team-relevant knowledge or a product such as a shared mental model' (p. 235). These processes require multiple inputs from team members potentially resulting in improved team performance. However, another aspect to team cognition, especially relevant to novice learners, is the role that team cognition plays in group learning. These two themes will be discussed in detail in the next section.

1. **Effective teamwork**

Although described separately in this study, team competencies include both taskwork and teamwork. Kluge (2014) uses the following comparison:

> *Taskwork [is] individually performing the technical components of the task based on mental models, ... whereas teamwork requires the application of non-technical team skills in order to integrate team members' individual contributions into a coordinated*

team performance for collaborative dynamic problem solving and decision making. (p. 93)

A nexus exists between good teamwork and successful performance in high-stakes environments, with poor teamwork being identified as a key factor in adverse medical events (Morey et al., 2002; Neily et al., 2010). Team leadership is clearly essential for team effectiveness (Zaccaro et al., 2012). This was clearly demonstrated by Group 2's failure to appoint a leader and the subsequent loss of team structure and team coordination, known as process losses (Zaccaro et al., 2012, p 83). Similarly, differing leadership behaviours enacted in the three pop-up simulations dramatically affected teamwork effectiveness.

Explicit teamwork behaviours were described in Chapter 3 with illustrative examples of both effective and ineffective teamwork and the resultant outcomes. It needs to be reiterated at this point that teamwork behaviours were introduced incrementally into the simulations over the course of second year. As mentioned previously, following the advice of Salas et al. (1992), teamwork skills were introduced after the development of taskwork skills. This resulted in many examples of suboptimal teamwork. However, many of these instances occurred prior to the particular teamwork skill being taught. Despite this, these examples are a useful basis for discussion and highlight the importance of addressing both cognitive and behavioural teamwork skills in an equivalent manner to other skill-based learning.

In this first iteration of the coaching prototype intervention, there was less focus on the teaching of teamwork skills compared to taskwork skills. Teamwork skills were introduced over the course of the second-year simulations in an opportunistic rather than planned manner resulting in inconsistencies in the teaching. Of particular note was allowing Group 2 to progress without formal appointment of a leader in the early sims, and the resultant dependence that group had on the coach as 'de-facto' leader. Inadequate coaching support for team leader appointment resulted in low team member motivation and poor response coordination, as evidenced by their early simulations. These problems are often caused by inadequate training (Salas, Bowers, & Edens, 2001), as was the case in this situation where the coach needed to be more proactive in promoting teamwork behaviours. With hindsight, this needed to be addressed and supported from the outset. Particular teamwork behaviours, highlighted in the Chapter 3 examples, need to be formally taught and learned through the aggregation of instances of teamwork episodes in such a way that they too are stored and retrieved when required.

Local instruction teamwork guidelines, based on the following themes identified from the data and supported by the literature, have been developed to support coaching at this level:

- Team leadership
- Role allocation
- Teamwork skills.

4. Appointment of a team leader is crucial to the success of the simulation.

4. Principle: A team leader is appointed at the commencement of every simulation and continues in this role for the entirety of the simulation with support from the coach.

Justification: Team leadership is essential for team effectiveness. This is especially so in the setting of clinical deterioration. Medical students are not usually taught teamwork in any other component of the curriculum, and yet are expected to work as part of a team as a junior doctor.

Explanation: Members of novice homogenous groups are reluctant to nominate a leader as they feel inappropriately prepared for such a role and appear to often lack confidence in attempting this role. In some emergencies the performance environment may be chaotic, with many people involved but nobody in charge. The person best capable of managing the situation should actively take the role of team leader (St. Pierre et al., 2008). Ineffective leadership in the setting of clinical deterioration is due to the leader not assuming responsibility for the leadership position and not acting accordingly (St. Pierre et al., 2008). Leaders impact team effectiveness by facilitating team problem-solving through cognitive processes, such as shared mental models, coordination processes, such as task allocation, and team cognition (Alonso & Dunleavy, 2013). As discussed earlier in this chapter, including teamwork skills as part of simulations adds extra elements over and above taskwork, which in turn increases cognitive workload. The time and cognitive resources required for team coordination and communication are affected by ‘concurrent taskwork demands’ (Kluge, 2014, p. 133). For this reason, the ‘whole task’ of effective teamwork is deconstructed into teamwork part tasks introduced over a period of time as each previous part task becomes automated. Incremental progression through teamwork elements, including effective leadership behaviours, as distributed practice ensures an accumulation of teamwork instances, in turn supporting teamwork skill retention in episodic memory. Teamwork procedural knowledge, such as sharing mental models, situation awareness, and effective communication strategies, should be provided by the coach 'in the moment' and subsequently faded away for future instances (Kluge, 2014).

Coaching implications: The leadership role is unfamiliar to medical students, and as such, reassurance is required that they will be supported in that role by the coach. The coach should position him- or herself at the foot of the bed next to the leader. This gesture reassures the student that they are supported and tacitly encourages the learner to remain in that position for the duration of the case. Students often assume that as leader they are responsible for all activity and decision-making throughout the case. The use of a basic analogy such as ‘You are just the traffic cop controlling the intersection and directing the traffic’ helps to simplify the role at this stage. As teamwork expertise develops and the concept of being a team leader is less threatening, one extra dimension to the leadership role is added at each simulation, such as the responsibility of the followers to support leadership decisions through sharing of mental models.

5. Each student performs every designated patient management role at least once.

5. Principle: All team roles, including that of team leader, are experienced by all team members.

Justification: Students develop a holistic understanding of all essential roles through practice opportunities and observation of others in that role.

Explanation: Students develop an understanding of what each role entails, in particular the concept of task interdependence and the need for a coordinated approach to achieve team cohesiveness. Additionally, students experience ‘task fixation’ while focused on a procedural skill, such as inserting an intravenous cannula, and through that develop an appreciation of its negative impact on situation awareness. Team effectiveness is achieved when interdependent team members with different roles work cooperatively with each contributing to problem-solving (Kluge, 2014). Effective team 'interaction dynamics' over a series of varying performance instances will enhance leadership expertise within a team (Zaccaro et al., 2102, p. 103). Experiencing a variety of roles enables students to appreciate the task demands of each role and the potential impact that has on the ability to contribute to team collaboration. For example, focusing on procedural skills imposes a heavy cognitive demand on novices and limits their ability to have an overall perception of the current situation. It is difficult to have that appreciation unless it has been experienced firsthand. Additionally, students appeared to develop team member schema similarity through observing others previously perform the same role. In this context, team member schema similarity refers to team members' overlapping cognition based on their interpretation of the situation from the perspective of their particular role (Rentsch & Woehr, 2004).

Having a shared understanding of what each role entails also enables team members to develop strategies for coming to each other's aid during times of need (Hinsz, 2009, p. 54). Additionally, teams that have a more accurate awareness of each other's roles and actions can communicate more efficiently by spontaneously transferring appropriate information as required (MacMillan, Entin, & Serfaty, 2009). Lastly, experiencing all of the roles that make up the management of clinical deterioration enhances the sense of value of participating in and becoming part of a community of practice (Lave & Wenger, 1991).

Coaching implications: The coach ensures that students rotate through each role and encourages teamwork behaviours to promote team collaboration to achieve coordination. In order to maintain flow, it is preferable to coach individual team members in a 'one-on-one' coaching format when they are performing in different roles. This prevents interruption to the simulation for the entire team when the focus of the coaching is only directed at one student. Some students find particular roles easier than others and may not require coaching. Over time, they all become proficient in each of the roles. If possible, team members should have more than one opportunity to experience each role in order to implement learnt behaviours from their first attempt and from observing others in the same role.

6. **Specific teamwork skills are sequentially introduced over the duration of the program.**

6. Principle: Effective teamwork behaviours are explicitly addressed and scaffolded according to the needs of the group.

Justification: Teamwork behaviours are acquired through the accumulation of instances of teamwork events.

Explanation: Opportunities for learning teamwork skills need to be provided in parallel to taskwork skills to enhance real-time coordination of team activity and prevent process losses. Effective teamwork skills are required to successfully complete Loop 1 and 2 taskwork. As with taskwork skills, the objective with teamwork skills is to offer students a basic framework on which to guide their actions and to aid in the development of teamwork characteristics schema. According to Kluge (2014), teamwork skills are best taught to intact teams as opposed to individual members, so they can integrate and jointly practise teamwork skills.

There is scope to coach teamwork skills to a higher level, as mentioned in the previous paragraph, but as a starting point, three teamwork attributes apart from leadership have been selected as the basic fundamentals for this level of learner. All three emerged from the data as essential for effective management of clinical deterioration. Situation awareness, shared mental models, and effective communication form the basis for providing appropriate learning opportunities in the simulation program described in this study.

(a) Situation awareness

Situation awareness signals that 'people always have to be orientated in the entirety of their environment in order to be able control it' (St. Pierre et al., 2008, p. 98). It is required to prevent errors of fixation and to correct faulty mental models of a situation (St. Pierre et al., 2008). In order to develop situation awareness, team leaders need to use all available cues, information, and activities to construct a relevant image of the situation. It then needs to be updated as the situation changes, and all elements need to be continually reassessed for their relevance. The complexity of the situation imposes a heavy task and information load on the leader, especially if the situation has not been previously experienced, as is the case for novice learners. Two critical factors that ensure that situation awareness is not threatened must be supported by the coach: the team leader must remain at the foot of the bed in order to visualise all aspects of the situation, and the team leader must not become involved in taskwork or other activities that will cause a distraction. Novices often feel that they are not contributing to the team activity if they are removed from the taskwork. However, as the intricacies of the leadership role evolve, students develop a greater understanding and appreciation for its complexity. According to Kluge (2104), further instances and learning episodes will increase situation awareness and accuracy. This was apparent in the fourth-year simulations when the urgency of the situation was rapidly assessed by the team leader.

(b) Mental models

In an emergency situation, communication is required to align the mental models of each team member (St. Pierre et al., 2008). Sharing mental models creates a context within which decisions can be made and the cognitive resources of the entire group can be utilised (Stout, Salas, & Fowlkes, 1997). This is especially relevant for junior doctors, often the first to be called to the bedside in clinical deterioration, when interacting with an interprofessional, ad hoc team. Differing clinical approaches results in different behavioural roles, which are often unknown to each other. According to St. Pierre et al. (2008), the major prerequisite for successful interprofessional teamwork is a shared mental model. Mental models develop as a result of experience and are stored in 'episodic' memory for later retrieval, as discussed in Chapter 2. Tulving (2002) coined the phrase 'mental time travel' (p. 2) in relation to retrieval of stored memories from episodic memory.

(c) Effective communication

i. 5 for 5 – taking 5 seconds to plan the next 5 minutes – is a communication strategy, taught and utilised at several major hospitals, that provides timely updates for the team. It is an opportunity to succinctly convey the current situation to all team members and to ensure that accurate mental models are shared. Team collaboration at this point also offers opportunities for joint problem-solving and decision-making. Regular 5 for 5 updates are ideally called in situations when all available information has been collected to inform the situation, when patient status changes, or during times of low workload. The coach can identify these opportunities and prompt the team leader or a team member to utilise a 5 for 5 so that ideal circumstances are appropriately demonstrated to the team.

ii. Closed-loop communication is a communication sequence involving a three-step process of a

- message being sent by the sender
- message received, interpreted, and acknowledged by the receiver
- confirmation by the sender that the message was received and appropriately interpreted by the receiver. (Salas et al., 2012, p. 46)

At first students appear to find this three-step process complex, lengthy, and awkward, especially when communicating with team members who are well known to them. However, with encouragement and prompting from the coach, it becomes more familiar and examples of it succinctly clarifying situations were evident in the data.

Coaching implications: Teamwork consists of a behavioural (specific concrete behaviours) and a cognitive (team-related knowledge) component, both of which need to be taught (Kluge, 2014). Fundamental teamwork skills such as the sharing of mental models, situation awareness, and effective communication strategies are introduced when appropriate. This is usually when taskwork becomes more automated, freeing up cognitive space to allocate time and attention to teamwork skills. Once the concept of team leadership has been accepted by the learners, other teamwork skills can be introduced in a distributed fashion, thus increasing the complexity and diversity of the simulations. A rule of thumb here is one new skill per simulation; for example:

Simulation 1 – Leader appointed and positioned

Simulation 2 – Appropriate taskwork role allocation

Simulation 3 – Concept of situation awareness

Simulation 4 – 5 for 5 communication strategy

Simulation 5 – Concept of mental models

Simulation 6 – Closed-loop communication

The coach provides practical suggestions in action to demonstrate or explain teamwork skills; for example, while standing at the foot of the bed with the team leader, articulate how he or she is able to maintain situation awareness through remaining in this position and not becoming fixated on a task. The coach also points out salient times for team negotiation opportunities to share mental models through 5 for 5 communication techniques. Increasing complexity can further be introduced to teamwork task development if it matches the group's zone of proximal development; for example, deconstructing an overarching theme of 'mental model' into more specific teamwork mental models such as *task-related* (team mental models and task knowledge), *team-related* (mental models of the capabilities and characteristics of team members), *process-related* (team mental models of communication, leadership, and coordination) and *goal-related* (team mental models of goals, objectives, and achievement) mental models (Wildman et al., 2012, p. 92). Team members holding different mental models may feel reluctant to speak up and this can be encouraged by the coach through articulation strategies.

2. Team cognition for *learning*

Team cognition is critical to effective teamwork and team performance (Fernandez et al., 2017). Cooke, Gorman, and Winner (2006) describe team cognition as cognitive activity occurring at team level through interaction among the individual team members. Team cognition therefore depends on the sharing of mental models and situation awareness. Furthermore, Zaccaro et al. (2012) claim that 'decisions emerging from group interaction are superior in quality to those made by the group's most capable member' (p. 83). For novice learners, sharing of individual cognition not only ensures that team members have a common understanding of the patient status, but also that they also *share their propositional knowledge* to promote a team-based understanding of *how that knowledge applies* to the current situation.

Effective communication strategies such as the 5 for 5 time-out technique therefore serve a second function in affording metacognitive opportunities for students to learn from each other in an emergent fashion. As a result, a team mental model of propositional knowledge such as physiology, pathophysiology, and aetiology is discussed and shared. Metacognition is group members' understanding of how information is processed and how cognitive tasks are performed. 5 for 5, in association with coaching episodes such as articulation techniques, made the students' thinking 'visible' to others.

Emerging from the data in this study is the extra dimension to group cognition of not only contributing to team effectiveness in *managing* the patient but also contributing to team *learning about* the clinical presentation. Examples from Chapter 3 on teamwork attributes demonstrate team cognition episodes as achieving both of those goals. One could argue that group-learning exercises in general enable sharing of information and robust discussion, which contributes to learning. A unique feature of simulation is the added dimension of situated learning and active participation in action, discussed in Chapter 1, which provides a powerful environment for authentic learning opportunities based on social interaction and collaboration. It is essential that metacognitive practices are promoted through coach-led modelling of expert thinking and coach-initiated opportunities for student articulation in combination with student-led communication strategies. This supports not only group cognition in regard to the clinical situation, but also the sharing of bioscientific knowledge underpinning the patient presentation.

5.2.2.4 Cognitive support

Coaching implications are included in all of the aforementioned local instruction guidelines. One overarching guideline is offered here as a broad approach to coaching in general.

7. An in-game coach provides support and scaffolding as required.

7. Principle: The cognitive apprenticeship model supports learning through relevant coaching strategies based on individual and group zones of proximal development, while sustaining a state of flow during the simulation action.

Justification: An in-the-moment facilitation style is considered the most appropriate for learners at this level, which enables the degree of task difficulty to be adjusted in action if required.

Coaching implications: An awareness of how much support to provide and subsequently fade is one on the most challenging aspects to the coaching role. Within a group, the zone of proximal development for some learners may be similar, but there are likely some students whose zone is quite different. Referring to the learning frameworks developed from this study and having clear instructional goals can guide coaching requirements. This can involve a mental ‘tug of war’ for the coach, but it is important to remain cognisant of the distributed nature of the simulation program, which provides future opportunities to introduce new skills. Constant assessment and ongoing monitoring of the zone of proximal development is a crucial feature of the coaching role.

Explanation: There is a perception often held by learners in simulation that the instructors are not on the 'same side' as the learners; that the instructors are going to create a scenario that is overwhelming and sets learners up to fail. This has historically grown out of the original objective of healthcare simulation that was designed for more senior clinicians to experience managing rare and life-threatening events in order to improve practice. 'Being thrown in at the deep end' was an oft-quoted saying associated with simulation-based activities, hence the 'life-raft' analogy described in Chapter 1 in reference to pause-and-discuss-style simulations. In-game facilitation and the concept of the coach 'being on the same side' as the learners is a crucial concept. This resonates with Lave and Wenger's (1991) concept of a participation in a community of practice and its emphasis on 'decentring common notions of mastery and pedagogy' (p. 94). Thus, learners and the coach engage in the simulation action together to create their own community of practice.

Cognitive apprenticeship highlights the importance of supporting learning by 'enabling students to acquire, develop and use cognitive tools in authentic domain activity' (Brown et al., 1989, p. 39). There is a heavy cognitive demand on students participating in simulation. The combination of learning a new complex system (the simulator), the introduction of a patient management framework with high element interactivity, managing teamwork activities to support taskwork completion, coupled with *thinking* and *doing* at the same time is a potentially overwhelming situation. The coach needs to manage cognitive load through the deconstruction of tasks into achievable units and ensure that learners are inside their zone of proximal development at all stages of learning progression. Also, as an experienced clinician, the coach can relieve learners of some of the more difficult tasks in a collaborative manner.

8. Cognitive supports are provided as scaffolding and are faded as appropriate.

8. Principle: Cognitive supports in the form of performance aids such as action-cue posters, whiteboards, etc., not usually found in the clinical environment, support medical student learning without detracting from clinical fidelity.

Justification: High extraneous cognitive load can be offset through the use of cognitive supports to free up working memory for learning.

Coaching implications: The coach has the function of providing enough scaffolding to ensure successful task completion, but as learners progress, they need less support. Fading of cognitive supports may need to be negotiated between the group and the coach. The premature withdrawal of the Loop 1 action-cue poster at the demand of the students may have a detrimental effect on learning.

Explanation: The final learning objective of the program is the completion of complex tasks from memory; as such, performance aids should be faded as learning progresses and eventually dispensed with by the end of the second-year program. In the early simulations, the posters serve as 'schema substitutes' for novice learners, as those schemas were are yet developed and stored in long-term memory. Cognitive supports become redundant as expertise develops.

9. The development of coaching skills is complemented with opportunities for feedback and reflection.

9. Principle: Facilitated post-simulation reflective discussion and feedback augments future coaching performance.

Justification: The newly described in-game coaching role differs pedagogically from traditional simulation facilitation and requires constant monitoring and development in order to support the evolution of the role.

Coaching implications: An experienced coach provides specific feedback to novice coaches based on the standards and role expectations described in the local instructional guidelines. The structure of the feedback sessions may take different forms. Timely, post-hoc targeted feedback involves addressing specific issues that arise during the simulation. Video reflexivity using video-recordings of coaching activity is a more in-depth activity that utilises examples of simulation action on which to base the discussion and facilitate future development.

Explanation: The full gamut of simulation faculty development is outside the scope of this research. However, the basic principles of reflective practice and peer support in the coaching role is one aspect of such development. Advancement of the in-game coaching role requires a structured framework of implementation based on the novice coach's zone of proximal development in relation to progression of coaching skills development. Critical analysis of coaching performance using cognitive apprenticeship principles as a template to discuss coaching action and highlight performance issues is a vital aspect to the overall development of the role.

5.3 Design principles

The goal of this design research study was to introduce two interventions into a medical student simulation curriculum to achieve a desired goal. In this case, the two interventions were:

- the inclusion of clinical deterioration as a component of the existing simulation curriculum
- the redefined facilitation role of in-game coach to support learning.

The desired goal was to measure the learning, transfer, and retention of patient management skills as a result of those interventions. According to van den Akker (1999, p. 9), design principles can be better presented in a form of heuristic statements like:

> *If you want to design curriculum X [for the purpose/function Y in context Z], then you are best advised to give that curriculum the characteristics A, B and C [substantive emphasis], and to do that via procedures K, L and M [procedural emphasis], because of theoretical and empirical arguments P, Q and R.*

By following this format, the design principles developed from this study are presented as the following:

If you want to design curriculum - a simulation program for the purpose of enabling medical students to learn, transfer, and retain acute patient management skills over an extended period of time, then you are best advised to give that curriculum the characteristics of:

1. A longitudinally embedded simulation program providing distributed instances of patient management episodes in order for students to accumulate examples in memory through task repetition
2. Appropriate cognitive support through in-game coaching supported by learning frameworks and provision of aide-mémoires
3. Increasing complexity and diversity of cases accompanied by appropriate fading of scaffolding predicted in part by learning frameworks.
4. Gradual, concurrent introduction of cognitive and behavioural teamwork skills to ensure an accumulation of instances of teamwork episodes
5. Opportunities to consolidate learning through pop-up simulations that provide conditions for learning transfer
6. Refresher training after an extended retention interval to improve retrieval strength

and to do that via procedures:

distributed learning practices, cognitive load theory, flow theory, and

because of theoretical and empirical arguments:

1. Distributed learning. Distributed learning practice provides repeated instances for the development of episodic memory. Experiences are actively formed into contextualised knowledge structures in long-term memory (Kluge, 2014). Episodic memory involves re-experiencing previous experiences. Simulation training for medical students facilitates the acquisition of episodes, as it is the only source of such skill development in the management of clinical deterioration. The distributed nature of the simulation experiences produces an increase of storage strength and retrieval strength of previously experienced episodes resulting in long-term retention.

2. Cognitive load theory. Coaching techniques need to optimally manage rather than overload working memory during learning. In particular, high extraneous cognitive load negatively affects learning by overloading working memory. Extraneous cognitive load is kept to a minimum while intrinsic and germane load are optimised by controlling interelement activity through appropriate scaffolding by the in-game coach.

3. Flow theory. Flow has been described as a state of cognitive efficiency and intrinsic enjoyment whereby a person feels at one with the activity (Csikszentmihalyi, 1975). The three variables of flow – concentration, interest, and enjoyment – in combination create the ultimate state in which learners are fully immersed in learning. Continuous in-game coaching and monitoring of student actions promotes flow. These design principles are presented as a blueprint in Table 30.

5.4 A simulation curriculum blueprint

The curriculum blueprint represented in Table 30 sets out the longitudinal program that formed the basis of this research. Heavily underpinned by cognitive apprenticeship guidelines, it provides the rationale for each stage of the program from initial familiarisation to the simulated environment at the commencement of second year through to refresher training in fourth year.

Table 30. A simulation curriculum blueprint

Course description: A longitudinally embedded simulation program for medical students					
Course objective: To provide opportunities for repeated application of patient management frameworks through distributed practice with in-game coaching support					
Stages	**Detail**	**Rationale**	**Content**	**Coaching**	**Other considerations**
Familiarisation	Intro sims	Deconstruct Loop 1 steps using worked examples	Sim 1 – DRSAB Sim 2 – CDEFG Introduce teamwork as a concept only	Break down every step into components, demonstrate each one, and have students practise each step At completion of Sim 2, provide a worked example of leadership	Reassure students about cognitive support provided in each sim. They have a heavy cognitive load at this time trying to remember all the steps in addition to the complexity of the simulation environment and system Associated theory: Cognitive load/distributed practice

Acquisition	2nd year sims linked to curriculum	Distributed learning with increasing complexity and diversity of cases	Loop 1 Loop 2 Merge when appropriate Add teamwork as appropriate	Provide cognitive-apprenticeship-style coaching episodes with appropriate scaffolding and fading Use learning frameworks to guide sims, coaching, and learning	Appointment of team leader crucial in 1st sim Other teamwork attributes are introduced incrementally as taskwork skills become automated Use mnemonics and acronyms when possible Associated theory: Flow
Practice	2nd year pop-up sims at completion of 2nd year program	Opportunity to practice transfer in ad hoc groups	Real-time scenarios with supportive nurse to prompt if required	Coach/nurse hybrid model	Limited coaching if possible Discuss challenges of ad hoc groups and random clinical events at completion of sim
Refresher	4th year sims x 2	Opportunity to retrieve prior learning	Real-time scenarios Smaller group size	No coach Use learning frameworks as an assessment tool	Post-hoc debriefing including observers Reflect on both past and new learning

Note:

Sim(s) = simulation(s)

DRSABCDEFG = Danger, response, send for help, airway, breathing, circulation, disability, exposure, (don't ever) forget glucose

As a conclusion to this section, the following table directs the reader to the specific sections of the thesis addressing data analysis and resultant research outputs aligned with each of the research questions. Although the table represents each question individually, all of the contributing questions are interrelated and serve to contribute to the overarching research question.

Table 31. Research questions and data outputs

Research questions	**Output**
To what extent does a longitudinally embedded patient management simulation program develop medical students' ability to systematically approach patient management, and what evidence is there of retention and transfer of these skills?	
RQ 1. What taskwork skills are students required to develop in order to manage acute	Taskwork learning frameworks in clinical deterioration and clinical reasoning (see

patient management?	Tables 14 and 17, Chapter 3)
RQ 2. How does teamwork impact on the students' capacity to complete those skills?	Seven teamwork skills necessary for successful completion of the simulated cases have been identified (see section 3.2.2, Chapter 3)
RQ 3. How might instructional design in simulation be developed to support the processes required to develop those skills?	Table 10 in Chapter 2 maps the simulation curriculum across the cognitive apprenticeship learning domains. Section 5.4 in Chapter 5 offers a simulation curriculum blueprint. There is ongoing intervention refinement through reflection and modification (see section 5.2.2, Chapter 5)
RQ 4. How can a new role of in-game coach enhance learning in simulation?	Coaching actions and aims are described in section 4.2 of Chapter 4
RQ 5. How can optimal conditions for learning in simulation be operationalised?	Extended uses of the learning frameworks are described in section 5.2.1 of Chapter 5. Local instructional guidelines have been developed to describe the optimal conditions for learning in simulation (see section 5.2.2,)

5.5 Reflections and future implications

5.5.1 Reflections

A vital component of the evaluation process in educational design research is that of reflection. McKenney and Reeves (2012) describe this phase as 'active and thoughtful consideration of what has come together in both research and development' (p. 80). Included in the reflections phase of this particular study is the highly personal aspect of self-reflection: that of one's own coaching performance. The focus of educational design research is on the meaningful impact of the design interventions on the quality of the teaching and learning outcome (Reeves, McKenney, & Herrington, 2011). One way of assessing quality is through self-reflection of one's performance.

Many hours of data coding including viewing my role as in-game coach provided multiple opportunities to scrutinise my own performance, which has promoted deep reflection on the overall process of this research. In particular, making visible how I, as coach, interacted with students and impacted on their performance provided valuable insights into the coaching process. As a form of 'video-reflexivity' (Iedema, Long, Forsyth, & Lee, 2006) analysis, I was able to identify both effective and ineffective coaching practices to contemplate for future refinement of the coaching intervention. It afforded me opportunities to view myself in practice and identify opportunities for change and improvement in coaching style. I was able to identify some typical coaching interactions that were common to all groups, which I can now anticipate and plan for in advance. For example, in some instances when I used prompting to remind students about a particular task, it would have been better to have used modelling to make my thinking about that task more visible. This relates back to the coach monitoring and assessing the learners' zone of proximal development and judging *in the moment* which coaching strategy works best for that particular situation. Of particular benefit was the opportunity to be made aware through video reflexivity of both effective and ineffective 'habitual ways of being' (Carroll, Iedema, & Kerridge, 2008, p. 10) that I was unaware of.

As an experienced and insightful simulation facilitator with a clear understanding of how I was trying to develop the role of in-game coach, I felt I could fairly astutely and accurately review my own performance. In particular, observing myself in action via the video recordings has enabled me to develop a new skill in that, rather than becoming part of the action, I am now able to metaphorically 'stand back' during the simulations and 'view' myself as coach, almost looking in from the outside. This is another aspect of the coach's situation awareness. Previously described as the coach being aware of concurrent student action occurring during the simulation and prioritising which aspect of the action needed coaching, this new dimension of situation awareness relates to the coach's dynamic presence within the action and where that ideally sits.

5.5.2 Implications

Within educational design research, the findings generated from the reflective phase, in association with the empirical findings, are subsequently used to refine both the interventions and the resulting design documents such as the learning frameworks and the local instructional guidelines (McKenney & Reeves, 2012). Subsequent coaching of ongoing cohorts of medical students since the data collection phase of this study has afforded opportunities to continually refine the two educational interventions introduced as a basis for this study.

5.5.2.1 Refinements to Intervention 1: Teamwork and taskwork skills required for acute patient management

With an initial focus of the study on the taskwork required in patient management, not unsurprisingly teamwork came to the fore as the predominant factor in successful execution of taskwork skills. Yet during the introduction of clinical deterioration into the simulation curriculum, the teaching of teamwork skills was on a more ad hoc nature than the carefully planned teaching of patient management frameworks. Despite knowing that teamwork is a crucial factor in patient outcomes during clinical deterioration, it was overlooked as a priority. On reflection, the reason for this was possibly that teamwork had not been a factor when the simulation program over previous years had focused only on clinical reasoning as a case-based exercise. These insights have led to refinements in the simulation program. First, teamwork is now explicitly taught in a sequential manner. Leadership is taught in the introductory simulations and then other teamwork skills are introduced once taskwork skills have been developed. Second, the simulation program has increased in size with the introduction of four extra simulations in second year. This gives every team member the opportunity to undertake each role within the simulations twice. This allows for both increased observational opportunities for students to view others in a particular role and to practise the role again after the first attempt.

In order for students to appreciate the development of their acute patient management skills, video reflexivity is now routinely utilised in student discussion group sessions at the completion of second year. Providing a guided opportunity for students to view the video recordings of their first and last simulations is now included in the curriculum as a reflective exercise in which students are able to acknowledge their learning progression over time. Finally, from a taskwork instructional design perspective, the high element interactivity of the circulation assessment has been deconstructed in the early simulations in an attempt to reduce the complexities students face in its application.

5.5.2.2 Refinements to Intervention 2: The role of in-game coach

As discussed as an introduction to this chapter, an added dimension to situation awareness has added an intuitive component to my coaching performance. However, in simulation practice, a more formal process of development and reflection is required for the role of 'coach'. First, in order to provide a comprehensive guide for coaches, further research focusing on expert practice identified through analysis of video recordings of coaching episodes could underpin a coaching framework – in a similar style to the learning frameworks developed for use in this research. For example, using Marzano's (2012) template of the 'Organisation of The Art and Science of Teaching' could form the basis for identification and description of best practice in coaching (see Table 32 as an example).

Table 32. Coaching framework (adapted from Marzano, 2012)

Coaching framework
Simulation segments involving clinical deterioration
Question: *What will I do to ensure students adhere to the DRSABCDEFG framework?* Element 1: What are some ways to ensure the cycle is completed appropriately? Element 2: What is the best way to encourage students to fix as they go? Element 3: How do I encourage students to recycle through the cycle?
Question: *How will I ensure that clinical deterioration has been addressed prior to clinical reasoning problem-solving?* Element 1: How do I ensure students recognise the importance of initial stabilisation? Element 2: What are some ways to introduce the concept of premature closure in diagnosis? Element 3: How can I encourage thorough data collection prior to diagnosis?
Question: *How do I ensure that teamwork skills are introduced appropriately?* Element 1: How can I identify when students are ready to progress in their teamwork skill development? Element 2: How can I best support the team leader in appreciating the importance of that role? Element 3: How do I ensure that all students rotate through appropriate roles?
Question: *How do I incorporate 'new' practical knowledge into the simulations?*

Element 1: How do I chunk large amounts of information into useable 'bits'?
Element 2: What are some strategies for promoting group cognition?
Element 3: How can I encourage all students to contribute to problem-solving?

Second, opportunities for coaches to utilise guided video reflexivity as a form of practice development would complement the feedback they receive after each simulation session. Designing simulation scenarios to meet the specific learning requirements of an apprentice coach risks jeopardising the learning outcomes for students participating in the simulations due to conflicting design objectives. However, videorecording enacted student actions within a specific context could be utilised as trigger videos for discussion regarding coaching interventions. The aforementioned coaching framework could form the basis for video analysis of performance and assist the coach to structure changes to coaching style and identify developmental goals.

5.6 Summary

From a pragmatic perspective, learning frameworks and several local instruction guidelines have been developed as initial prototypes of design instruction to support the delivery of simulation-based learning. As is the iterative nature of design research and given that this study was a 'slice' of an entire design process, further revisions to the outputs have been introduced since the end of this study. According to Collins, Joseph and Bielaczyc (2004), this approach of 'progressive refinement' requires design researchers to put 'a first version of a design into the world to see how it works' in order to revise the design 'until all the bugs are worked out' (p. 18).

The rationale for the intervention of introducing a simulation program at second-year level is to offer opportunities to students for repeated and distributed instance-based practice of clinical management strategies early in the curriculum in order to be committed to long-term memory and retrieved when required as junior doctors. Emergencies such as clinical deterioration are among the most challenging situations in medicine. A potent mix of stressful demands such as the need for rapid decision-making, a lack of comprehensive information, time pressure, the need to interact with unfamiliar team members, and the level of anxiety make the situation extremely challenging (St. Pierre et al., 2008). Additionally, in such a critical situation, the awareness of potential to harm a patient because of the urgency of the situation and the often chaotic environment can become another major stressor (St. Pierre et al., 2008). In the Callaghan et al. (2018) integrative review, the results showed that junior doctors do not feel adequately prepared to recognise and manage deteriorating patients due to a lack of knowledge and inadequate preparation to do so. They suggest that effective simulation education could influence junior doctors' capacity and confidence for managing patient deterioration and that this should be a core component of the education continuum. However, there is no suggestion that such education be introduced at medical student level, despite the findings that showed that even after one year, junior doctors continued to question their ability to manage acutely unwell patients.

The results of this study show that deteriorating patient taskwork and teamwork skills taught during second year are retained to a high level even after an 18-month retention interval during which time students were not required to use the skills and knowledge acquired during the initial training phase. According to Kluge (2014), a lack of opportunity to apply learnt skills is a strong negative predictor of skill retention and performance level. From a retention perspective, Bjork and Bjork's (1992) theory of disuse assumes that forgetting is not due to storage capacity, but is based on both *retrieval strength* (e.g., accessing a memory when required) and *storage strength*, which represents how entrenched a representation is in memory. In other words, storage strength is based on how well something is learned and retrieval strength on the probability of something being recalled in response to recognisable cues. The results of this study can be explained by the distributive nature of the initial simulation program providing opportunities for repeated practice spaced over a 8-month period. Distributed practice increases storage strength, which subsequently slows down the loss of retrieval strength caused by disuse, which leads to improved performance after a training interval (Bjork & Bjork, 2006). Furthermore, because storage strength, once developed, becomes permanent, it carries over to refresher training. The fourth-year simulations could be considered refresher training as they aimed to 're-establish a specific skill level that was acquired at the end on initial training, which should be re-established after a certain time interval during which the skill was not required to be recalled' (Kluge et al., 2012, p. 2437). It appears from this study that two immediately consecutive simulations in fourth year produced the conditions necessary to demonstrate high storage and retrieval strength.

5.7 Limitations

This research was undertaken at a single site, so analytical generalisation of student learning results may not be possible. However, from a case-to-case generalisation perspective, one of the major outputs of the study is the development of local instructional guidelines that are designed to assist others in different contexts. The relationship between the researcher as coach and focus group interviewer was acknowledged as having a potential impact on the study, but steps were taken to mitigate these issues (see section 2.6 in Chapter 2). Although only three groups of students participated in the study, it resulted in many hours of video-recorded simulation action and a huge amount of data, which provided a good sense of learning progression, retention, and transfer. The three core educational design research phases of analysis and exploration, design and construction, and evaluation and reflection were achieved in this study. However, an ongoing iterative cycle of further refinement of the educational interventions was beyond the scope of this study. Plans for those refinements form the basis for discussion in the next section.

5.8 Implications for medical student education

Simulation clearly offers potential for medical student learning, particularly in the setting of clinical deterioration. Conceptualising the entire patient management experience as triple-loop learning enables clinical deterioration to be contextualised into the broader patient encounter. Triple-loop theory supports coaching through acting as a learning progression guide for coaches enabling them to identify appropriate merging of loops as opposed to premature entry. Providing repeated instance-base experiences reinforces and automatises learnt frameworks early in the curriculum alongside concurrent learning in clinical reasoning. In association with a longitudinal program, repeated exposure increases storage and retrieval strength of both teamwork and taskwork schema making it available for recall despite a long retention interval. Refresher training in fourth year further strengthens storage and retrieval and extends the next retention interval. Junior doctors need the acute patient management skills required to deal with clinical deterioration, which is often unexpected, stressful, and time pressured. In particular, the rapid assembly of an ad hoc team requires expertise not usually taught in medical school. There is real potential for appropriately designed and structured simulation to equip medical students with such skills to recognise and effectively -manage clinical deterioration.

5.9 Future research

The nature of educational design research is such that continual refinements to interventions is ongoing – some of which has already occurred, as discussed in section 5.5.5.2 of this chapter – and this will continue both formally and informally as an aspect of reflective practice. However, future research is required to further apply instructional design principles to simulation-based learning activities in order to ensure that these activities are serving the purpose for which they are used.

5.9.1 Learning, retention, and transfer

First, in direct relation to this study, in order to assess both learning transfer from simulation to clinical settings and retention of patient management frameworks under stressful real-world conditions, the 15 students who were part of this research will be followed up at the end of their first junior doctor year. This future research project will analyse the impact of the simulation program on both their ability and confidence to practise acute patient management in those situations. Second, research into the usefulness of the local instruction guidelines is needed to explore their applicability for other purposes such as a feedback tool for learners or an assessment tool for learning. Lastly, this thesis deals with medical students; however, a similar methodology using the local instructional guidelines adapted for further use in other contexts such as rural areas or for ongoing junior doctor training would increase the ease with which the guidelines could be distributed and applied.

5.9.2 Coaching

More research is needed on the new role of simulation coach. As discussed in section 5.2.2 of this chapter, future research could further develop the role of the coach by identifying best practice guidelines designed as coaching frameworks to support its establishment. Current simulation facilitation styles are well entrenched within the field; as such, a related question is user acceptance and buy-in by simulation facilitators of this new coaching role. Further research, especially in relation to enablers and barriers to acceptance of this role, is required. Additionally, from the view of the learner coach, their level of experience is another interesting concept to explore. Despite their expertise, more senior clinicians could be considered novice learners if the content is new. The suitability of the coaching role in other domains requires further research to understand how best to support learning.

5.10 Conclusion

The findings from this study reveal that acute patient management teamwork and taskwork skills required by junior doctors can be taught to, and retained by, medical students in realistic simulated environments through a cognitive apprenticeship learning format. However, this requires a deliberate, consistent and distributed approach that supports skill retention through increases in storage and retrieval strength. Attention to simulation instructional design via the development of local instruction guidelines underpinned by theory that best supports learner requirements is crucial in developing such a program. Learning frameworks mapped against desired student actions support learning, feedback, coaching, and research. This study has witnessed the progression of medical student expertise along a learning continuum that places them at a competent level as they embark on their journey to being a junior doctor. Therefore, in response to the major research question, a longitudinally embedded patient management simulation program can develop medical students' ability to systematically approach patient management and support the retention and transfer of these skills.

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Appendix A. Literature Review Methodology

Data bases searched included:	**Terms entered for searching included:**
British Education Index ERIC CINAHL Clinical Key Cochrane Library Google Scholar Medline (Ovi simulation and gaming, serious games, instructional simulation styles, d, Web of Science, ProQuest, EBSCOhost) Minerva PubMed Central Science Direct Scopus	**Medical terms:** clinical deterioration, clinical reasoning, deteriorating patient, diagnostic reasoning, expertise in medicine, medical student learning, taskwork, clinical learning, design, decision-making. **Education terms:** learning theory, cognition, memory, learning retention, learning transfer, cognitive apprenticeship, apprenticeship, cognitive load, cognitive apprenticeship, zone of proximal development, flow theory, instance-based theory **Simulation terms:** simulation learning theory, clinical simulation, medical simulation, medical student simulation, simulation and training, simulation-based learning, instructional design **Teamwork terms:** teamwork, team cognition, decision-making in teams

Appendix B. Plain language statement

Plain Language Statement for participants

THE UNIVERSITY OF MELBOURNE

Dear MD2 student,

I am writing to invite you to participate in a research project I am currently undertaking. Research details are as follows:

University:	University of Melbourne
Departments:	Melbourne Graduate School of Education
Project Title:	Simulation in the MD program: Learning to Practice Medicine or Practicing to Learn Medicine?
Researchers:	Prof David Clarke – d.clarke@unimelb.edu.au Responsible Researcher Prof Geoff McColl – gjmccoll@unimelb.edu.au Co-Researcher Jennifer Keast – keastj@unimelb.edu.au Student Researcher
Degree being undertaken:	Doctor of Education

During MD2 and MD4, there is a compulsory simulation component to the curriculum where, as a group, you manage a patient (mannequin) in the RMH Simulation Laboratory with a facilitator to guide you through the process. You have already been familiarised to the simulation environment, the mannequin and the simulation program for the year. The aim of this project is to look at the learning outcomes of a longitudinal simulation program which teaches a structured approach to every patient presentation underpinning the diagnostic reasoning process. Potential benefits of this study include:

- development of an evidence-based teaching style for best practice simulation
- evidence of how best to utilise simulation within the MD curriculum
- contributing new knowledge to the healthcare simulation community

Should you agree to participate in this project, the simulations you participate in will be video recorded for later analysis. You will not be tested in any way, nor do you have to fill out any forms or questionnaires. During your simulations you will be unaware of the recording process as the cameras are discretely located in the ceiling of the simulation room. You will not be required to do anything that you would not normally do during your simulations and therefore there is no risk involved. These recordings are merely recording every day classroom activity. They will be safely and securely stored as per the University guidelines and destroyed after five years.

Melbourne Graduate School of Education
100 Leicester Street | The University of Melbourne Victoria 3010 | Australia
T: +61 3 8344 8285 **F:** +61 3 8344 8213 **W:** www.education.unimelb.edu.au

Appendix C. Consent form

Melbourne Graduate School of Education

CONSENT FORM

Project Title: Simulation in the MD curriculum: Learning to Practice Medicine or Practicing to Learn Medicine?

Researchers:
Professor David Clarke d.clarke@unimelb.edu.au Responsible Researcher
Professor Geoff McColl gjmcoll@unimelb.edu.au Co-Researcher
Ms Jennifer Keast keastj@unimelb.edu.au Student Researcher

This project is being undertaken for research purposes only. Involvement in this project is entirely voluntary and you are free to withdraw at any time, and free to withdraw any unprocessed identifiable data previously supplied.

By signing this consent form, you are agreeing to have your regular MD2 and MD4 simulation scenarios video-recorded specifically for this research. You also agree to participate in a one-hour focus group at the end of MD2 and MD 4 which will be audio-recorded.

All data will remain confidential and be stored according to University protocol. I am required to inform you that there are legal limitations to data confidentiality and it is possible for data to be subject to subpoena, freedom of information request or mandated reporting by some professions. Also, due to the small sample size, participants may be identifiable.

Once signed and returned this consent form will be retained by the researcher.

Name:

Signature:

Group:

Date:

Please include your email address if you would like to receive a Report Summary or a link to the relevant URL at the completion of the study.

email:

HREC: 1545724 **Date:** 7/03/2016; **Version:** 2.

Melbourne Graduate School of Education
100 Leicester Street | The University of Melbourne Victoria 3010 | Australia

Appendix D. The Melbourne Medical School Curriculum

The University of Melbourne Doctor of Medicine (MD) is a four-year full-time course undertaken after the completion of an undergraduate degree.

It comprises:

- One year of integrated bioscience and clinical learning featuring an innovative case-based teaching approach (First year)
- Two core clinical training years which facilitate learning with patients in a wide range of settings (Second and third year)
- MD Research Project in which each student is immersed in a single medical discipline and completes a research project (Fourth year - first semester)
- A capstone semester in which students "rehearse" the skills required for effective and safe clinical practice (Fourth year - second semester)
- An annual medical conference to provide opportunities to interact with leaders in research, policy and clinical healthcare.

YEAR ONE
Subject
Foundations of Biomedical Science
Principles of Clinical Practice
Student Conference
YEAR 2
Subject
Principles of Clinical Practice
Student Conference
YEAR 3
Subject
Principles of Clinical Practice
MD Research Project
Student Conference
YEAR 4
Subject
MD Research Project
Transition to Practice
Student Conference
ELECTIVE CLINICAL PLACEMENT
Subject
Clinical Elective

Appendix E. Example of completed Loop 1 framework

Group: 3
Simulation: 3
Date: 18/8/2016
Rotation: Surgery
Case: Acute pulmonary oedema
Time: 12.12.32–16.50.94 = 4.38 minutes

<table>
<tr><th></th><th>Sequence</th><th>Skill progression</th><th>Findings</th></tr>
<tr><td>D</td><td>Assess danger</td><td>Checks for danger</td><td>NB Assumption of no danger</td></tr>
<tr><td>(Intro)</td><td>Commences patient interview</td><td>Introduces self to patient
12.17.59</td><td></td></tr>
<tr><td rowspan="3">R</td><td rowspan="3">Assess patient’s response in the correct sequence</td><td>Ask orientating questions about person, time, and place
12.55.12</td><td>Orientated</td></tr>
<tr><td>OR assess response to voice</td><td>Disorientated and/or drowsy</td></tr>
<tr><td>OR assess response to pain</td><td>If not responding appropriately, send for help</td></tr>
<tr><td>S</td><td>Send for help</td><td>As and when required</td><td>Sends for help at any stage of the DRSABCDEFG assessment as required</td></tr>
<tr><td rowspan="7">A</td><td rowspan="7">Assess airway</td><td>Examines mouth</td><td>Recognises of normal airway</td></tr>
<tr><td rowspan="3">Listens for airway noises
13.21.97</td><td>Recognises normal airway</td></tr>
<tr><td>Notes type of sound</td></tr>
<tr><td>Uses airway manoeuvres and adjuncts if appropriate</td></tr>
<tr><td>Unable to clear or manage airway</td><td>Sends for help</td></tr>
<tr><td rowspan="4">Counts respiratory rate and observes for symmetry and pattern
13.03.43</td><td>Recognises normal respiratory rate</td></tr>
<tr><td>Recognises hypoventilation/tachypnoea</td></tr>
<tr><td rowspan="4">B</td><td rowspan="4"></td><td>Recognises asymmetry</td></tr>
<tr><td>Recognises abnormal pattern</td></tr>
<tr><td rowspan="2">Auscultates lungs
13.40.20</td><td>Notes presence or absence of sounds
Percusses if absent</td></tr>
<tr><td>Notes normal or abnormal sounds</td></tr>
</table>

		Applies probe to measure oxygen saturation 12.48.92	Recognises normal oxygen saturation
			Recognises hypoxia and commences appropriate oxygen therapy if required
			Recognises hypoxia and commences inappropriate oxygen therapy
C	Assess circulation	Notes skin colour, skin temperature, and/or diaphoresis	Notes normal
			Notes cool/warm
			Notes pale/flushed
			Notes clammy/sweaty
		Observes heart rate on monitor	Notes normal heart rate
			Notes abnormal heart rate
			Notes irregular waveform
		Palpates radial pulse and notes pulse character 12.39.59	Notes normal heart rate
			Notes abnormal heart rate
			Notes regular/irregular
			Notes bounding/normal/thready
		Measures blood pressure 16.19.90	**Recognises** hypotension/normotension/**hypertension**
		Checks mucous membranes	Notes dry or moist
		Assesses JVP 16.46.53	**Recognises** low/normal/**elevated**
		Checks capillary refill	Notes speed
		Checks urine output 15.34.40	**Notes amount**
		Performs 3-lead ECG	Recognises heart rhythm
		Recognises abnormalities and inserts IV cannula if required	Recognises fluid overload
			Recognises hypovolaemia and commences appropriate IV fluid replacement
			Unable to correct hypotension/hypovolaemia – sends for help
D	Assess	**Checks pupils**	**Recognises normal pupils**

	neurological disability	**13.45.53**	Recognises pupil abnormality
		Tests limbs	Recognises normal limb movement/strength
			Recognises abnormal limb movement/strength
			If neurological deficit detected – sends for help
E	Expose patient	**Performs top-to-toe examination front and back 13.33.77**	Identifies normal examination
			Identifies abnormal skin condition, oedema, inflammation, rash, scars, infection, surgical sites. Examines the abdomen
		Measures core temperature 13.44.32	**Recognises normal body temperature**
			Recognises hyper-/hypothermia
FG	Don't ever forget glucose	Measures blood glucose level	Recognises normal blood glucose level
			Recognises hypo-/hyperglycaemia
			Administers glucose if hypoglycaemic

Note:
DRSABCDEFG = Danger, response, send for help, airway, breathing, circulation, disability, exposure, (don't ever) forget glucose
ECG = Electrocardiogram
IV = Intravenous
JVP = Jugular venous pressure

Appendix F. Example of a Loop 1 timeline

Group: 1
Simulation: 4
Date: 7/7/2016
Rotation: Emergency
Case: Anaphylaxis
Time: 13.43.20-22.23.92 = 8.8 minutes until Loop 2

Time	Action	Step
13.43.20	Commences patient interview	
13.43.67	Counts heart rate and notes pulse character	C
13.55.09	Asks orientating questions about person, time, and place	R
14.41.18	Looks in mouth	
14.54.10	Applies probe to measure oxygen saturation	B
15.01.22	Observes heart rate on monitor	C
15.17.90	Counts respiratory rate and observes for symmetry and pattern	B
15.26.52	Listens for airway noises	A
15.45.91	Measures blood pressure (normal)	C
16.06.47	Checks mucous membranes	C
16.25.64	Auscultates heart	C
16.27.78	Looks for signs of cyanosis	B
16.36.12	Auscultates lungs	B
17.56.50	Assesses JVP	C
18.55.90	Observes work of breathing	B
19.29.36	Checks pupils	D
19.37.60	Tests limbs	D
19.47.59	Checks blood glucose level	FG
20.07.82	Measures patient's temperature	E
20.13.67	Measures blood pressure (low)	C
20.13.75	Recognises abnormalities and insets IV cannula as required	C
20.25.59	Performs top-to-toe examination front and back	E
Omitted	Performs 3-lead ECG	C
	Checks capillary refill	C
	Observes colour, skin temperature, and condition	C
	Examines the abdomen	E
	Call for help – tachycardic/hypotensive/airway support	

Note:
ECG = Electrocardiogram
IV = Intravenous
JVP = Jugular venous pressure

Appendix G. Example of pop-up taskwork and teamwork framework

Taskwork framework
Pop-up: 1
Date: 20/10/2016
Topic: Iatrogenic narcosis postoperatively

Postoperative narcosis due to a morphine infusion overdose. The team needs to follow the Loop 1 cycle, and all relevant findings will lead them to the diagnosis. In particular, the students will need to support the airway and assist the breathing. The trigger needs to be stopped (a rule they've been previously taught is to stop all infusions if they are called to a deteriorating patient until they figure out whether or not the infusions are contributing to the problem). The circulation will also need some support. Once they discover the pinpoint pupils, in association with an altered conscious state and hypoventilation, they should be able to put the diagnosis together. They may discuss other differentials, but once they have these three findings, they need to reverse the morphine with naloxone and think about alternate analgesia.

In the pop-ups, the coach tried to play a less prominent role and acted more like a supportive nurse to see how they performed under those conditions, although some coaching requirements became apparent.

Action progressions numbered in **red**
Actions time stamped in **bold**
Prompts by nurse in **green**
(Brackets are actions that fit more than one category)

Time: 00.26.95–16.18.13 = 15.92 minutes
Time to airway support: 03.11.60 = 2.85 minutes
Time to high-flow oxygen: 03.32.07 = 3.06 minutes
Time to call for help: 05.11.82 = 4.85 minutes
Time to IV fluids: 07.07.44 = 6.81 minutes
Time to reversing narcosis: 09.53.93 = 9.27 minutes

	Introduces self and takes a brief history	Patient does not acknowledge	Takes a leadership role	1. **01.31.37** Team enters room and Cindy assumes the leadership position. Cindy asks what infusions are running and is told morphine. She allocates B and C	Cindy checked infusions but didn't request that they be turned off. She also asked what dose of morphine had been infused and was told a large amount
	Check response Regularly check on patient status	Patient only responds to pain	Recognises urgency of situation	2. **01.38.50** Daniel checks patient's response	
	Requests monitoring – Observes oxygen saturation, respiratory rate, heart rate, blood pressure	Low oxygen saturation Heart rate slightly low but ok Blood pressure lowish	Allocates roles appropriately	4. **01.52.44** Edward applies monitoring	Edward does not comment on the low saturation or the slightly low heart rate; Daniel comments that the breathing is slow
	Checks airway by looking in the mouth	Airway clear from obvious obstruction		3. **01.46.90** Daniel checks airway	Airway noises are evident but they go on to check breathing without opening the airway
	Listens for airway noises	Patient snoring Airway manoeuvres required to open the airway		7. **03.11.60** Daniel applies a jaw thrust	
	Commence high-flow oxygen +/- breathing assistance	Insert GUEDEL airway May use BVM to assist breathing		8. **03.32.47** GUEDEL inserted with good effect and high-flow oxygen administered	
	Call for help	MET call required	Retain or hand over leadership as appropriate Provide relevant and succinct handover to incoming help Prioritise and allocate tasks	Cindy was explicit in her tasks allocation and needed to list components of steps in order for the team to get the jobs done. Neither of the	

			appropriately Share mental model(s) Team members report back findings	other 2 team members were proactive – this may have resulted in her not sharing her mental models and making decisions with the coach/nurse instead 9. **05.11.82** MET called	
	Auscultates chest	Chest clear		5. **02.09.87** Daniel listens to chest but patient has an obstructed airway	
	Checks respiratory rate	Hypoventilating		**(4. 01.52.44)**	
	Turns off infusions	Morphine is infusing		10. **05.29.32** Cindy asks again about the morphine infusion and asks again about the dose the patient has received. The nurse responds that it is a large dose	
	Assesses C	Hypotensive and relatively hypovolaemic Patient has an IV cannula in situ, so fluid infusion rate needs to be increased		6. **02.59.70** Edward assesses circulation 11. **05.57.88** Edward finally measures the blood pressure, after another request from Cindy, and states that it's low 14. **07.07.44** Cindy requests that the IV fluid infusion rate be increased	Edward starts with urine output, mucous membranes, etc., and finishes with heart rate and blood pressure Cindy checks her cardiovascular history before increasing the IV fluids
	Assesses D	Pupils are pinpoint. They are unable to assess limbs die to altered conscious state		13. **06.30.95** Cindy asks for a pupil check	Once she gets a pupil finding she states 'let's see if she's had an overdose'

	Reverses narcosis	Should prioritise this while completing the cycle Watch for an elevation of conscious state, increased respiratory rate, and reversal of pupils Remove GUEDEL airway		**12. 06.27.45** After Cindy's 2nd discussion with the nurse about the morphine dose, she asks 'can we reverse it' and the nurse says 'yes' **17.09.53.93** Cindy requests naloxone followed by E **20. 16.18.13** Patient wakes up and **nurse prompts GUEDEL removal**	After this conversation, Cindy states 'can we double-check her pupils' so she's now thinking narcosis but hasn't stated it out loud to the team **09.27.55 The nurse prompts that the morphine infusion is still running** **12.52.07 Nurse/coach explains naloxone dosing and prompts them to consider alternate analgesia**
	Exposes patient			**15. 08.05.50** Cindy instructs the team to do E including looking for calf swelling	**The nurse suggests here that the naloxone for reversal is the next priority**
	Checks BGL	This could also be the cause of the altered conscious state		**16.08.16.83** Cindy requests a BGL – normal	
Loop 2	Reassess A and B regularly Consider escalating oxygen device if not done so already				
	Recycle through other relevant Loop 1 steps	Oxygen saturation, respiratory rate, heart rate, and blood pressure will improve after reversal		**18. 12.11.65** Cindy asks Daniel to recycle through but this doesn't happen	The blood pressure was not rechecked at all
	Consider differential diagnoses or complications	Aspiration		**8. 04.31.40** Cindy states she is worried about PE **19. 14.16.24** Cindy suggest a	Cindy doesn't ask the others what they think at this stage. Edward is trying to

				WCC and the nurse informs her that they were normal that morning	figure out how the blood pressure cuff works!!!
	Organise alternate analgesia				
	Reassure patient at regular intervals	Explain situation			

Note:

B = breathing
BGL = Blood glucose level
BVM = Bag-valve-mask
C = circulation
E = Exposure
IV = Intravenous
MET = Medical Emergency Team
PE = Pulmonary Oedema